2.0 SITE HISTORICAL OVERVIEW

2.1 SITE DESCRIPTION

2.1.1 Background

2.1.1.1 Gaseous Diffusion and the Need for Uranium Enrichment

In natural uranium, the fissile ^{235}U isotope accounts for only 0.711 weight percent (wt %) of the total uranium; the ^{238}U isotope accounts for more than 99%. Both nuclear weapons production and commercial nuclear power generation require higher concentrations of the fissile ^{235}U. The process of increasing the ^{235}U concentration in a uranium stream—and decreasing the concentration of ^{238}U—is known as uranium enrichment. ORGDP enriched uranium as UF_6 gas via the gaseous diffusion process for military purposes from 1945 to 1964 and for commercial purposes from 1965 until the plant was placed on standby in 1985.

In the gaseous diffusion process, a UF_6 feed stream having both ^{235}U and ^{238}U molecules is pumped into a barrier consisting of numerous porous tubes. The less massive $^{235}UF_6$ diffuses through the barrier slightly faster then the $^{238}UF_6$. The slightly enriched UF_6 stream thus created is fed to many subsequent stages of equipment, and the process is repeated until the desired level of ^{235}U enrichment is achieved. The series of connected stages is referred to as the enrichment cascade. The product produced by the gaseous diffusion enrichment process is UF_6 enriched in the ^{235}U isotope. The by-product or waste stream, which is referred to as depleted UF_6, or "tails," contains less ^{235}U than is found in nature.

All uranium fed into the gaseous diffusion enrichment cascade must be in the form of UF_6. The uranium feed is derived from two primary sources:

- Natural uranium that is mined as a uranium bearing ore and processed to an oxide, typically near the mine, and subsequently converted to UF_6 at a feed plant.
- Recycled uranium (RU) that has been used in plutonium or tritium production, research, or in commercial nuclear power reactors and has been processed to recover the uranium for reuse. RU contains trace quantities of TRU elements and fission products [generally at the level of parts per million (ppm) to parts per billion (ppb) in relation to the uranium].

2.1.1.2 Origins of ORGDP

ORGDP had its origins as one of three nuclear production facilities built in East Tennessee during 1942–1943 in support of the Manhattan Project. These facilities were constructed on approximately 90 square miles of undeveloped land west of Knoxville, Tennessee. Initially known as the Clinton Engineer Works military reservation, the area became known as Oak Ridge after World War II. The three Manhattan Project production facility sites were code-named Y-12 (site of an electromagnetic plant for uranium enrichment), X-10 (site of an experimental

plutonium pile and chemical separation facilities), and K-25 (the site of the gaseous diffusion plant). The first gaseous diffusion enrichment cascade was Building K-25; the names K-25 and ORGDP were synonymous throughout much of the plant's history. The K-25 enrichment cascade officially began operations in February 1945. In April 1945, construction began on K-27, a second gaseous diffusion facility built to provide low-level enrichment.

2.1.2 ORGDP Site

Located on a 1,500-acre tract approximately 11 miles west of the city of Oak Ridge, Tennessee, ORGDP eventually added three more gaseous diffusion buildings (K-29, K-31, and K-33) and encompassed more than 100 different facilities (Fig. 2.1-1). The plant ultimately became capable of enriching uranium up to 93% ^{235}U for defense purposes. Decreasing requirements for highly enriched uranium (HEU) for defense purposes resulted in the shutdown of ORGDP HEU facilities in 1964. As the U.S. Government began providing low-enriched uranium (approximately 2 to 5% ^{235}U) for commercial nuclear power reactors in the United States and other countries, ORGDP became an integral part of that effort.

Fig. 2.1-1. The ORGDP Site. The former Oak Ridge Gaseous Diffusion Plant and K-25 Site is now the East Tennessee Technology Park (ETTP).

The plant was officially shut down in 1987. Following the shutdown, the site became known as the Oak Ridge K-25 Site and served as the base for environmental management activities at the fives sites managed by DOE-ORO. In 1997, the site became known as ETTP. With the initiation of DOE's reindustrialization program at the site, inactive ETTP facilities are subleased to private-sector companies by the Community Reuse Organization of East Tennessee (CROET), a private, not-for-profit organization. The Bechtel Jacobs Company LLC serves as the management and integration contractor for DOE-ORO environmental management activities that continue to be based at the site.

2.1.3 ORGDP Evolution

Except for a brief period in 1945 when Building K-25 was the only gaseous diffusion facility producing enriched uranium, the ORGDP gaseous diffusion buildings have operated as an integrated unit. For example, when K-27 came on line, K-25 and K-27 operated much like a single plant or enrichment cascade. Over ORGDP's operating history, the plant's five gaseous diffusion buildings (K-25, K-27, K-29, K-31, and K-33) were linked together in a large number of different configurations. Once PGDP and PORTS began operations, the three DOE GDP sites worked together as an integrated operation (Fig. 2.1-2). To optimize use of resources, feed and product of different assays were shipped among the sites. Generally, PGDP shipped uranium that it had enriched to a lower level to ORGDP and PORTS for further enrichment. ORGDP provided some material it had enriched to PORTS for additional enrichment. And both ORGDP and PORTS enriched material for shipment to commercial customers and to other U.S. Government facilities using enriched uranium.

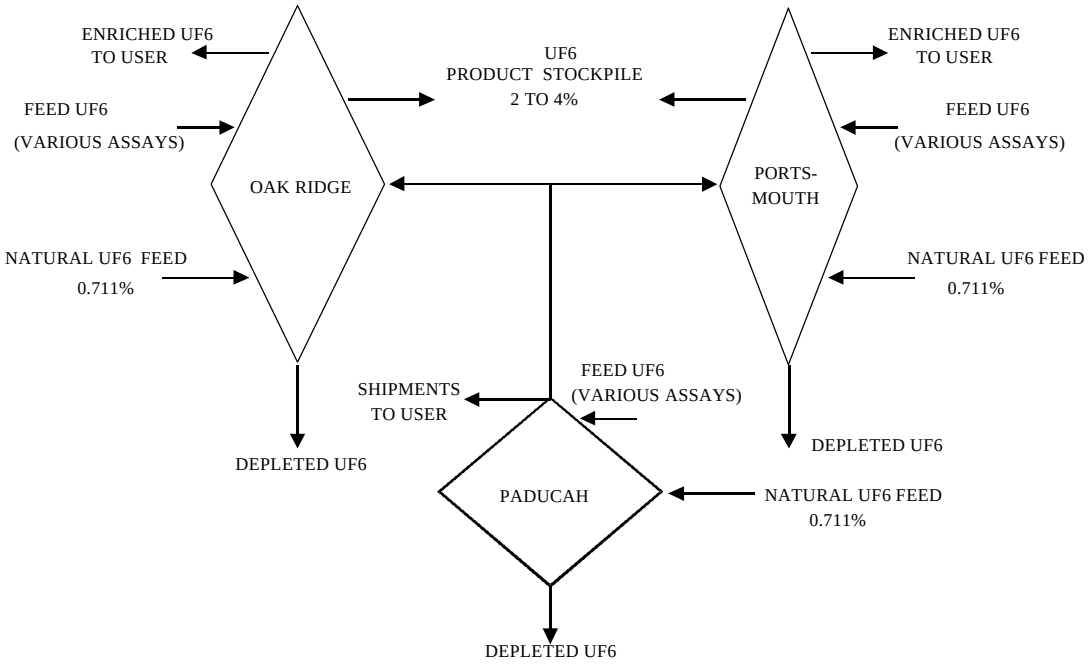


Fig. 2.1-2. DOE Gaseous Diffusion Complex.

Because process buildings at a site were connected, and feed and product moved among the GDP sites, contaminants had many potential pathways to reach various parts of the facilities. For example, ^{99}Tc introduced into a gaseous diffusion cascade in feed tends to travel up the cascade over time because it is lighter than ^{235}U. One might thus anticipate finding ^{99}Tc anywhere in the system above the feed point where the material was introduced. In addition, contaminants may have found pathways to buildings not directly involved in the GDP processes. For example, equipment may have been removed from a processing building and transferred to a non-processing building for repair. Although one can identify many potential pathways for contaminating various facilities at the site, the level of contamination that may be present is also very significant.

The following sections provide descriptions of the major configuration changes for the ORGDP cascade**.** Fig. 2.1-3 shows the locations of the principle facilities that are discussed. In reviewing these descriptions, one should view the configurations presented as the "base case" for a specific time period. Other configurations may also have been used. Factors influencing configuration variations include:

- When cells were taken off line for maintenance, the cascade would be reconfigured around the cells for the period they were out of service.
- The top product assay for any period was almost certainly not the only assay produced. Any assay below the top product assay would have been possible at any given time.
- Feed at various assays would have been fed at corresponding assay points in the cascade to avoid mixing different assays (and losing separative work).

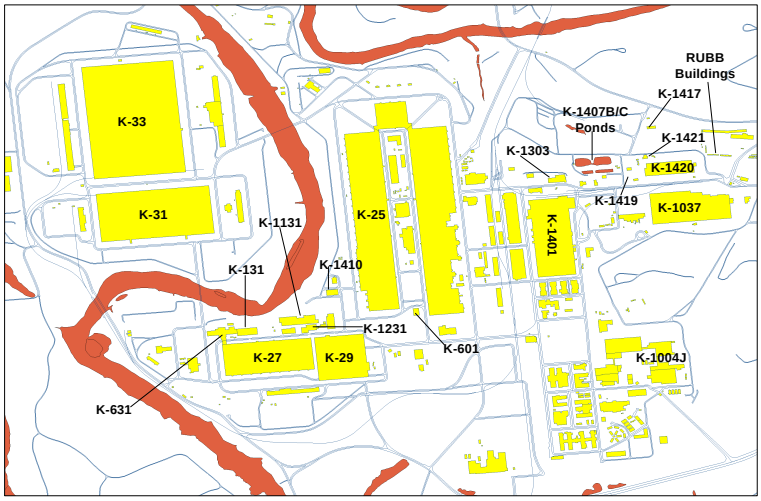
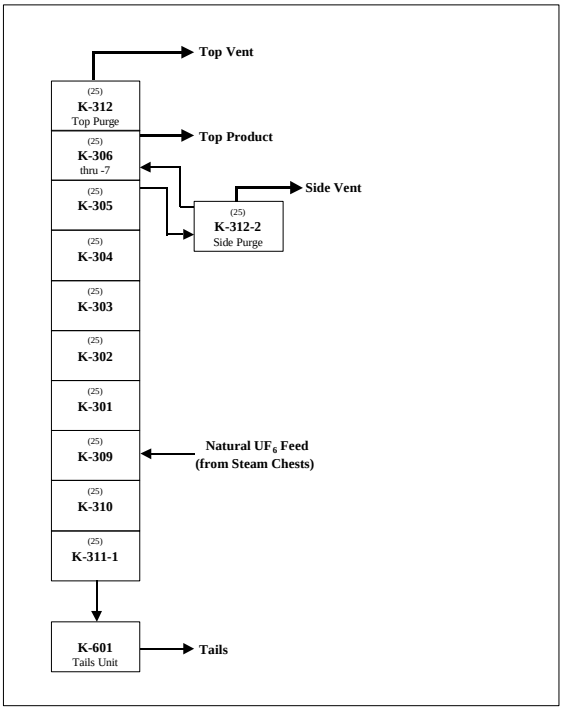


Fig. 2.1-3. DOE Gaseous Diffusion Complex RU Facility Locations.

2.1.3.1 August 1945 to January 1946 (Fig. 2.1-4)



The original cascade configuration was established in August 1945 when all stages of the K-25 building were placed on stream. The normal (.711% ^{235}U) feed point was in the K-309 section and was accessed via a series of steam chests. The K-601 building was the tails withdrawal facility. The top product withdrawal point was in the K-306-7 unit. The K-312 purge units, located in the cascade above the product withdrawal point, were used to separate light molecular gases (e.g., N_2, O_2) from UF_6. A side purge point was established at the top of K-305-12 to eliminate most purge gases from entering the K-306 section. K-312-3 was used as a top purge. The K-310 section and the K-311-1 section served as the tails-stripping sections of the cascade.

All feed entered into the cascade during this period was natural UF_6.

2.1.3.2 January 1946 to 1948 (Fig. 2.1-5)

In early 1946, Building K-27 construction was completed, and its units were placed on stream as quickly as feasible. The optimum K-25/K-27 cascade configuration that was established involved overlapping the stripping sections of K-25 with those of K-27 (with the K-25 stripping section K-309 at the top and the K-311-1 unit at the bottom of the stripping section). The normal feed location was in K-27 in the K-402-3 or K-402-4 units, depending on the cascade gradient. During this period, Building K-631 was placed in operation and became the tails withdrawal point. The product was shipped to Y-12 for further enrichment by the electromagnetic process. In January 1947, the product assay of ORGDP was increased from 30%U^{235} to 93% U^{235} and the Y-12 Plant electromagnetic process subsequently shut down.

All feed entered into the cascade during this period was natural UF_6.

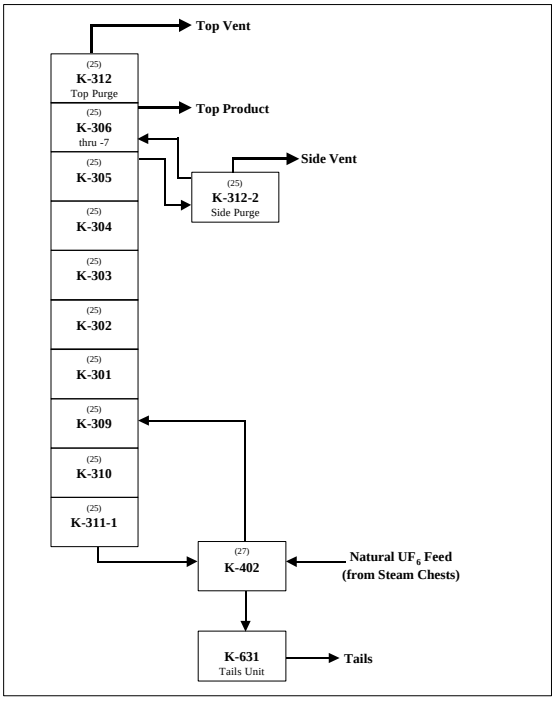


Fig. 2.1-5. Schematic Process Flow for ORGDP Cascade, 1946 – 1948.

2.1.3.3 1948 to 1951 (Fig. 2.1-6)

In order to produce 93% U^{235} efficiently, the ORGDP enrichment cascade had to be lengthened. This modification resulted in a significant change to the K-25/K-27 cascade configuration. To lengthen the cascade, the K-25/K-27 overlap was eliminated, and all stages were placed in series. The bottom of the cascade was K-311-1 (in Building K-25), and the tails went from this unit to Building K-631. K-631 remained the tails withdrawal point until the entire ORGDP was shut down. Above K-311-1 in the cascade was K-402 (in Building K-27) where feed from Building K-131 was introduced. Unit K-310 (in Building K-25) was fed from K-402, and the rest of the cascade above this point was in K-25. At the top of the cascade, the product withdrawal station and purge locations remained the same as in the previous period.

All feed entered into the cascade during this period was natural UF_6.

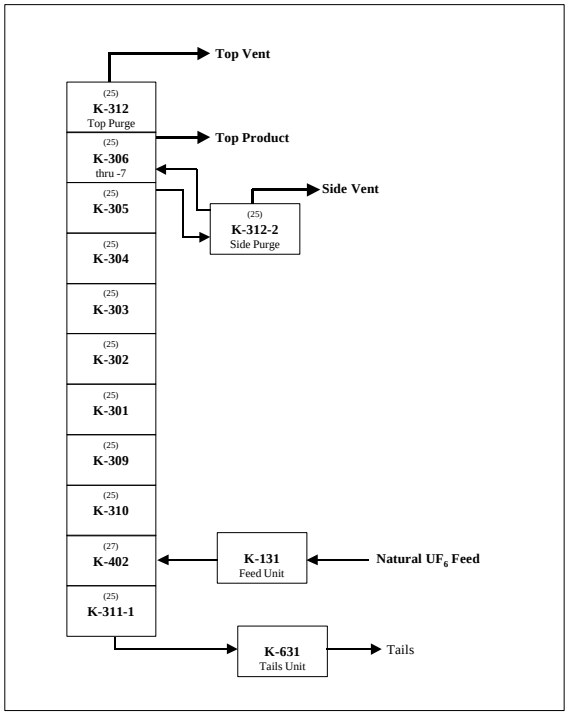


Fig. 2.1-6 Schematic Process Flow for ORGDP Cascade, 1948 – 1951.

2.1.3.4 1951 to 1952 (Fig. 2.1-7)

With demand for enriched U^{235} increasing at a rapid rate, the U.S. Government embarked on a large expansion program that included not only additions to ORGDP, but also the construction of GDPs near Paducah, Kentucky, and Portsmouth, Ohio. The third major processing building added to ORGDP was Building K-29 , which was located east of K-27. The K-29 cascade was inserted into the existing cascade between the K-402-1 and K-402-2 units of K-27. There were thus units in K-27 on either side of the K-29 units. This configuration necessitated major process gas piping changes in K-27. The K-311-1 unit in K-25 remained in the bottom position of the cascade, below the K-402-1 unit in K-27. Tails still went to K-631. At the top of the K-402 units in K-27 were the K-309 units in Building K-25. The cascade feed point was shifted to the K-29 units at the matched assay point. Some of the K-29 stages were thus in the tails-stripping section of the plant.

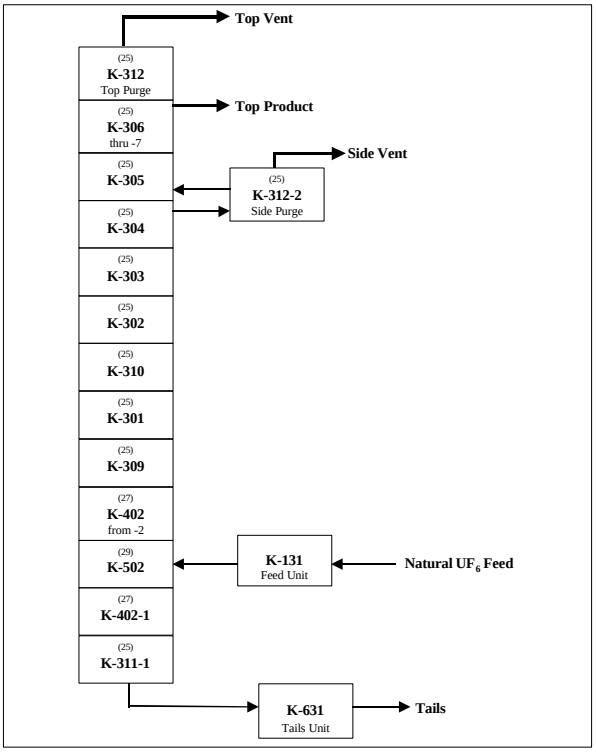


Fig. 2.1-7. Schematic Process Flow for ORGDP Cascade, 1951 – 1952.

The addition of 300 K-29 stages to the cascade resulted in a further increase in light gas contaminants leaking into the cascade and the higher concentration of light gases in the upper stages of Building K-25—up to the side purge withdrawal point in K-305-12. Such concentrations can result in the loss of sensitivity in detecting air in-leakage to the cascade. Because of this concern, the side purge point was shifted from K-305-12 to K-304-5.

All feed entered into the cascade during this period was natural UF_6.

2.1.3.5 1952 to 1954 (Fig. 2.1-8)

During 1952 to 1954, the U.S. Government's GDP expansion proceeded at a rapid pace. PGDP was brought on stream in this period. The overall optimum cascade configuration was an overlap between the PGDP and ORGDP sites. PGDP was used for the low-assay range of the enrichment process. PGDP fed normal material, as well as ORGDP tails shipped from ORGDP to PGDP. PGDP produced product above normal assay and was used as feed to ORGDP at the K-602 unit of ORGDP's new Building K-31, which was brought on line in the period because of increasing feed volumes. Normal feed was also fed into the K-602 unit.

During this period and beyond (1952-1961) ORGDP operated the on-site fluorination plant at K-1131 for both virgin and RU feed. (This facility is described in more detail elsewhere in this report.)

The K-31 stages were placed in the cascade between the K-29 stages (with K-502 at the bottom of K-29) and the K-27 stages (with K-402-1 at the top of K-27, but now the bottom of the overall cascade). The tails withdrawal point continued to be at K-631, with tails going to PGDP, as previously mentioned. The K-312-2 side purge unit was no longer adequate and was replaced by a new side purge at K-311-1 in K-25 (connected between K-309 in K-25 and K-402 in K-27). The K-312 unit continued as the top purge, and top product withdrawal continued to be at K-306 (both in K-25).

In 1952, RU was first received at ORGDP. In 1953, the first RU was fed into the ORGDP cascade.

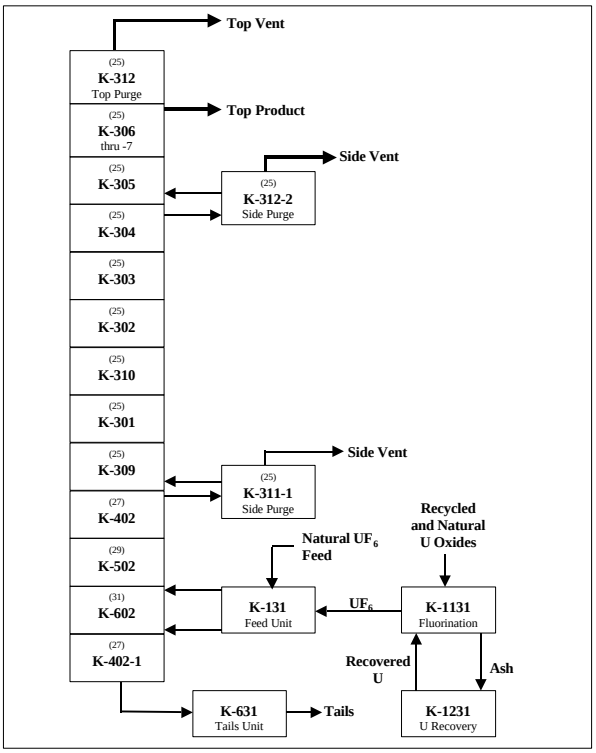


Fig. 2.1-8. Schematic Process Flow for ORGDP Cascade, 1952 – 1954.

2.1.3.6 1954 to 1957 (Fig. 2.1-9)

As the GDP expansion continued, Building K-33 was brought on stream. K-33 was integrated into the cascade between the K-602 units in Building K-31. Some of the K-602 units were now in the tails-stripping group. The area below K-602-1 was the bottom of the cascade, with tails withdrawal still performed in K-631. Normal feed and PGDP product feed to ORGDP was shifted to K-33 at the appropriate points in the cascade. The feed room constructed at K-33 proved to be much more convenient than the K-131 location.

During this period, many gas cooler leaks were experienced because of design problems. A K-101 coolant removal unit was placed in operation, with a cascade pigtail arrangement in K-303-1 for concentrating the coolant (C-816) that leaked into the cascade. The stages in K-303-1 (in Building K-25) were equipped with special barrier that permitted the coolant to

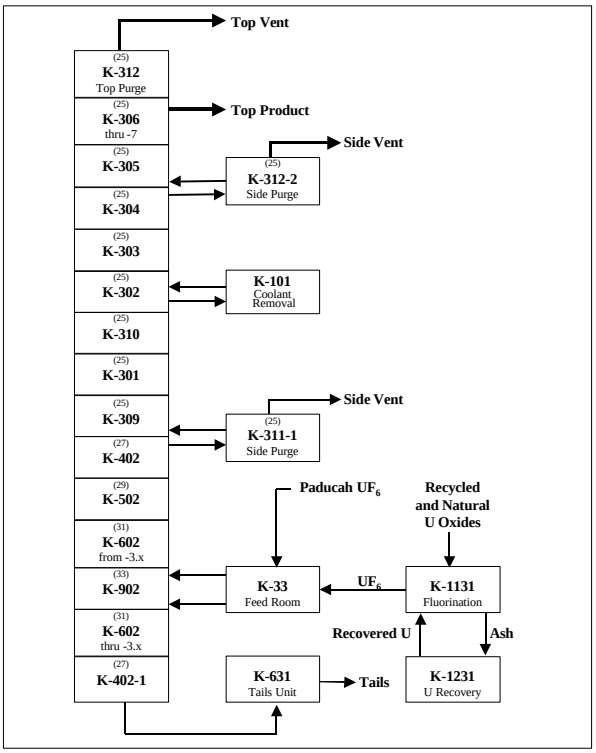


Fig. 2.1-9. Schematic Process Flow for ORGDP Cascade, 1954 – 1957.

accumulate at this location and subsequently be fed to the distillation unit in Building K-101 for separation from the UF_6. The coolant was returned to the coolant systems with some traces of UF_6. The side and top purges and top product withdrawal point continued as in the previous period

A few reactor returns were processed by ORGDP in 1955, and ORGDP continued to receive product from PGDP for use as feed.

2.1.3.7 1957 to 1959 (Fig. 2.1-10)

In 1957, the ORGDP powerhouse ceased supplying the K-306 section of Building K-25. Unit K-305-12 became the new top product withdrawal point and was tied to the K-312 top purge. The K-304-5 side purge point was eliminated. A new pigtail arrangement was established with the K-311-1 purge cascade as part of efforts to address Freon coolant contaminants. Other aspects of the cascade described in the previous period (i.e., the normal and PGDP feed and the tails withdrawal points) remained the same.

Reactor returns were processed by ORGDP in 1959, and ORGDP continued to receive product from PGDP for use as feed.

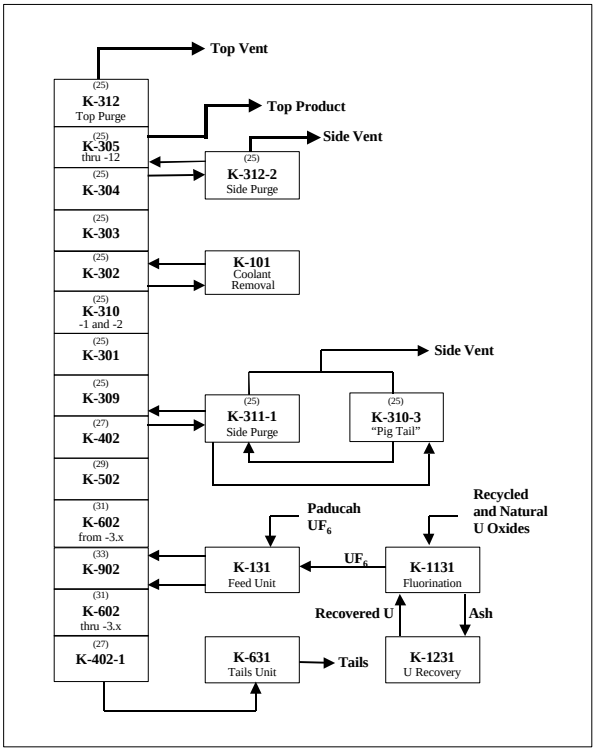


Fig. 2.1-10. Schematic Process Flow for ORGDP Cascade, 1957 – 1959.

2.1.3.8 1959 to 1961 (Fig. 2.1-11)

During the period, the top three units on K-305 section (i.e., K-305-10, K-305-11, and K-305–12) were shut down because of changes in power utilization and distribution. The ORGDP powerhouse was also shut down. The remaining cascade configuration and feed and withdrawal points did not change.

Reactor returns were processed by ORGDP in all years in this period, and ORGDP continued to receive product from PGDP for use as feed.

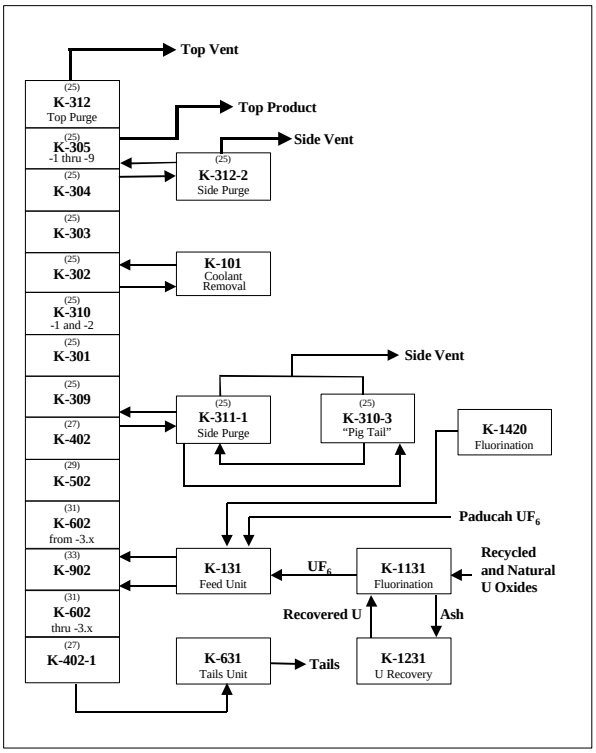


Fig. 2.1-11. Schematic Process Flow for ORGDP Cascade, 1959 – 1961.

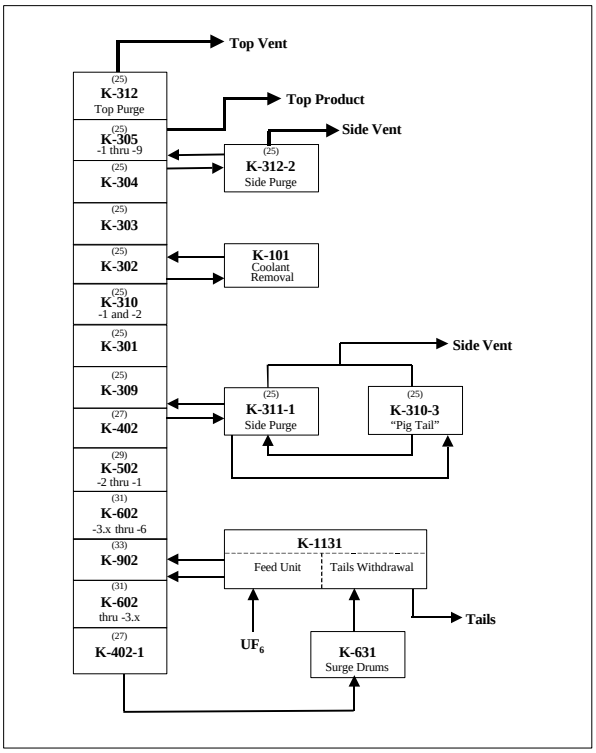


Fig. 2.1-12. Schematic Process Flow for ORGDP Cascade, 1962 – 1964.

2.1.3.9 1962 to 1964 (Fig. 2.1-12)

During 1962 to 1964, the cascade configuration remained unchanged from the previous period. The significant operational change involved the shutdown of the tails withdrawal facility in Building K-631. Tails withdrawal was shifted to Building K-1131 after the UF_6 feed production operations there were suspended. Tails were now withdrawn directly into cold traps before they were liquefied and drained in 14-ton cylinders. Also, the K-131 feed operation was terminated and transferred to Building K-1131. ORGDP feed and tails removal operations were now located in a single building.

Reactor returns were processed by ORGDP during the period, and ORGDP continued to receive product from PGDP for use as feed.

2.1.3.10 1964 to 1985 (Fig. 2.1-13 and Fig. 2.1-14)

In 1964, Buildings K-25 and K-27 were shut down—with the exception of the K-311-1 purge cascade and its K-310-3 pigtail operation (in K-25). In 1968, the K-502-3 unit in Building K-29 was shut down, and in 1977, the K-311-1 and the K-310-3 pigtail were replaced by the K-402-9 purge and the K-402-8 pigtail. The top product during the period was withdrawn from the K-413 unit. Feed and tails withdrawal in Building K-1131 continued. The bottom of the cascade was now the K-602-1 unit (in Building K-31), which tied directly into the K-631 surge drums floating on line prior to the tails withdrawal.

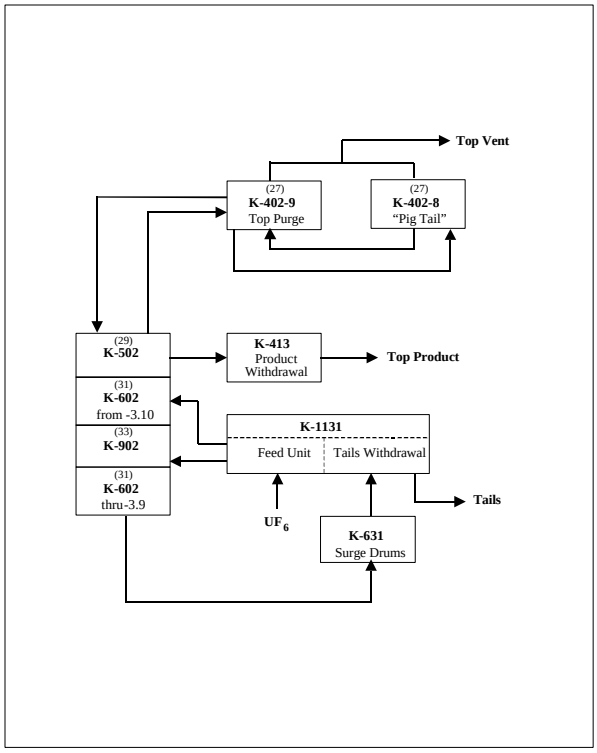


Fig. 2.1-13. Schematic Process Flow for ORGDP Cascade, 1964 – 1977.

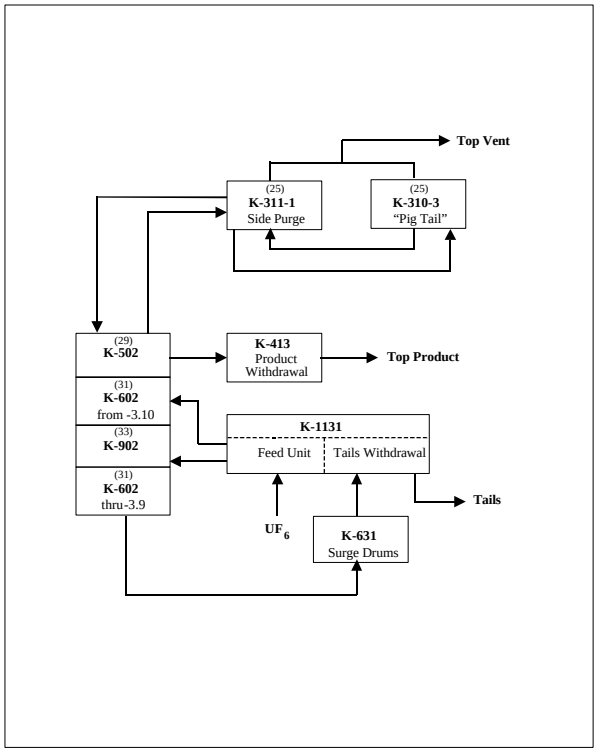


Fig. 2.1-14. Schematic Process Flow for ORGDP Cascade, 1977 – 1985.

Reactor returns were processed by ORGDP through 1984, and ORGDP continued to receive product from PGDP for use as feed. In June 1985, ORGDP was placed on standby; in 1987, the plant was permanently shut down.

2.1.3.11 Mixing of Process Equipment

There are good indications that there was very little mixing of equipment from point to point in the cascade during ORGDP's operational era. Some small parts, such as mechanical seals, could be interchanged relatively freely after reconditioning. However, because of differences in equipment sizes, compressors and converters could not be used outside their original buildings. In fact, because of special modifications, large equipment often could not be moved between units and, in some cases, could not be moved between enrichment cells.

Certain facilities that did serve the entire site could be contaminated with mixed material from all parts of the enrichment process. These facilities would include maintenance and decontamination facilities (e.g., Buildings K-1401, K-1410, and K-1420). Even within one cascade building, some equipment (such as the wet air pump, its associated seal exhaust, and the building exhaust ventilation system) served more than one unit and could be contaminated with RU material from throughout the building.

With exceptions cited in the preceding paragraph, contamination at a given point in the process buildings generally should be representative of a specific point in the enrichment process, with minimal influence of materials from other points in the process.

2.1.3.12 Improvement Programs

As previously described, the original facilities at ORGDP, PGDP, and PORTS were built and placed in operation in the late 1940s and the early to mid-1950s. Beginning circa 1956, an improvement program was undertaken to incorporate significant improvements in the separation membrane. In addition, because improvements in compressor technology had also been achieved, in the period from 1956-1962, essentially all of the compressors and converters in the low-assay portion of the cascade were replaced with higher-performance equipment. By the early 1970s, more improvements were developed that justified additional equipment change-out actions known as the Cascade Improvement Program/Cascade Upgrade Program (CIP/CUP), which continued until 1981 at ORGDP. Thus, there were large-scale equipment change-out programs collectively known as CIP/CUP in the low-assay diffusion cascades—in addition to the many exchanges of failed equipment over the course of the years. During 1951–1985, a total of 5,324 compressors, 2,983 converters, and 43,257 seals were replaced at ORGDP. This high amount of activity over many years created potential for RU contamination and exposure.

2.2 ORGDP OPERATIONS INVOLVING RU

Table 2.2-1, "ORGDP Cascade Evolution, 1945–1985" shows by time period ORGDP cascade buildings in operation and the feed, tails withdrawal, top product withdrawal, and purge points. RU was introduced into the ORGDP cascade beginning in 1953. The combination of the site evolution and the introduction of RU leads to a focus on the following operations as possible contamination points.

Table 2.2-1. ORGDP Cascade Evolution, 1945 – 1985

Period	Processing Buildings in Operation	Feed Point	Tails Withdrawal	Top Product Withdrawal	Purge Locations
Aug 1945 - Jan 1946	K-25	K-309 (K-25)	K-601 Bldg.	K-306-7 (K-25)	K-312 Top Vent K-303-12 Side Vent K-312-3 Spare Purge (all K-25)
Jan 1946 - 1948	K-25, K-27	K-402 (K-27)	Same as above	Same as above	Same as above
1948 - 1951	same	Bldg. K-131 to K-402 (K-27)	Same as above	Same as above	Same as above
1951 - 1952	K-25, K-27, K-29	Bldg. K-131 to K-502 (K-29)	Same as above	Same as above	Same as above
No RU prior to 1953					
1952 - 1954	K-25, K-27, K-29, K-31	Bldg. K-131 to K-602 (K-31)	Same as above	Same as above	K-312 Top Vent K-304-5 Side Vent K-311-1 Side Vent K-310-3
1954 - 1957	K-25, K-27, K-29, K-31, K-33	K-33 Feed Room	Same as above	Same as above	Same as above
1957 - 1959	Same as above	Same as above	Same as above	K-305-12 (K-25)	K-312 Top Vent K-311-1 Side Vent K-310-3
1959 - 1962	Same as above	Same as above	Same as above	K-305-1 thru -9 (K-25)	Same as above
1962 - 1964	Same as above	K-1131 Bldg.	K-1131 Bldg.	Same as above	Same as above
1964 - 1985	K-29, K-31, K-33	Same as above	Same as above	K-502 (K-29)	K-311-1 Top Purge and K-310-3 (1977) K-402-8 and K-402-9 (After 1977)

2.2.1 UF_6 Feed Preparation

UF_6 is required as feed for input into the cascade for enrichment. UF_6 feed enrichments ranged from depleted to natural to enriched wt % ^{235}U. Over the life of ORGDP, UF_6 feed came from a variety of off-site sources, including PGDP, commercial natural UF_6 producers (including Allied Chemical in Illinois and, later, Kerr McGee in Oklahoma), foreign reactor returns, and re-feed of tails. ORGDP also had the capability to produce UF_6 feed on site.

At the Hanford and Savannah River Plant plutonium processing facilities, after the irradiation of uranium fuel in reactors to produce plutonium and tritium, chemical processes were used to recover as much Pu as possible from uranium and separate both Pu and uranium from fission products and impurities. Because the chemical separation processes were not 100% efficient, the resulting RU that was shipped primarily to PGDP or ORGDP as "purified" UO_3 had trace quantities of the TRU element ^{237}Np and the fission product ^{99}Tc.

Following experimental operations in 1948, Building K-1131 (which was originally built in 1945 as a dry air plant for the K-25 cascade) was converted to a UF_6 preparation facility (Fig. 2.2-1), with production starting in 1952. From 1952 to 1960, ORGDP operated K-1131 as the on-site feed plant for both natural and RU UO_3 feed.

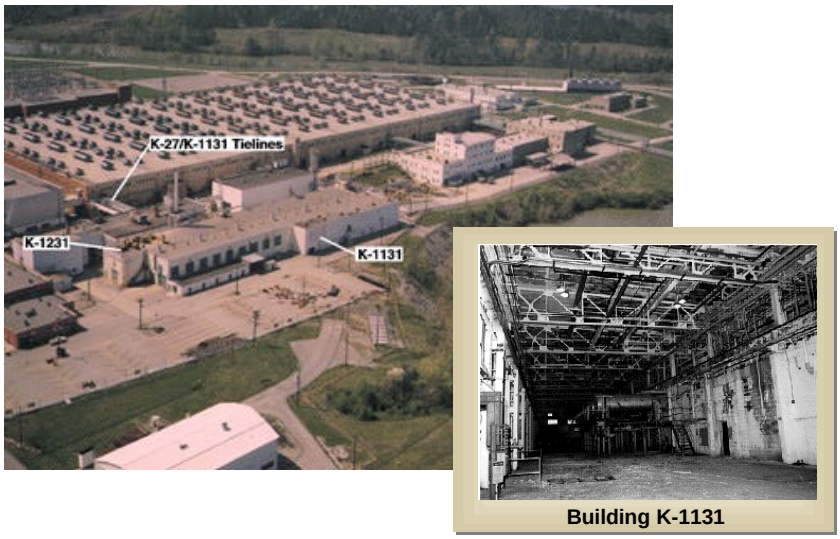


Fig. 2.2-1. K-1131 and K-1231 Exteriors and K-1131 Interior (Inset).

At the K-1131 feed plant, natural or recycled uranium (which was received as UO_3) was hydrogen reduced to UO_2. The UO_2 was hydrofluorinated to produce UF_4. The UF_4 was fluorinated in a flame tower reactor to produce UF_6 as feed for the gaseous diffusion process. The UF_6 was collected in large cylinders for transport to the K-131 cascade feed building. In 1960, the K-1420 building became involved in fluorination activities in addition to other activities related to decontamination and uranium recovery.

With the RU, no significant separation of the transuranics and fission products occurred during the reduction or hydrofluorination steps (UO_3 to UO_2 and UO_2 to UF_4). Transuranics, and to a lesser extent, fission products, were concentrated during the conversion of UF_4 to UF_6. Most of the Pu and a smaller fraction of the incoming Np formed nonvolatile compounds and were deposited with the ash. On the other hand, most of the feed ^{99}Tc was fluorinated to a volatile specie and was collected with the uranium in the UF_6 feed cylinders.

Metal canisters for ash collection and particulate filters to filter the UF_6 gas were attached to the fluorination reactors. Filters were cleaned and reused or treated as radioactive waste. Residual ash was removed from the tower and sent to Building K-1231 where the solids were size reduced in an ash pulverizer located at the west end of the building. The processed ash was

subsequently recycled to the fluorination tower. Some ash recovery activities were also conducted in K-1420. After successive re-feedings into K-1131 towers until it was no longer practical to recover the remaining uranium, the spent ash was discarded. Historical information indicates that the spent ash was packed and shipped to PGDP.

ORGDP operated K-1131 as the on-site feed plant until 1961. Fig. 2.2-2 presents K-1131 feed production totals as recorded in the *ORGDP Quarterly Reports* for each quarter reported from 1952 to 1963.[1]

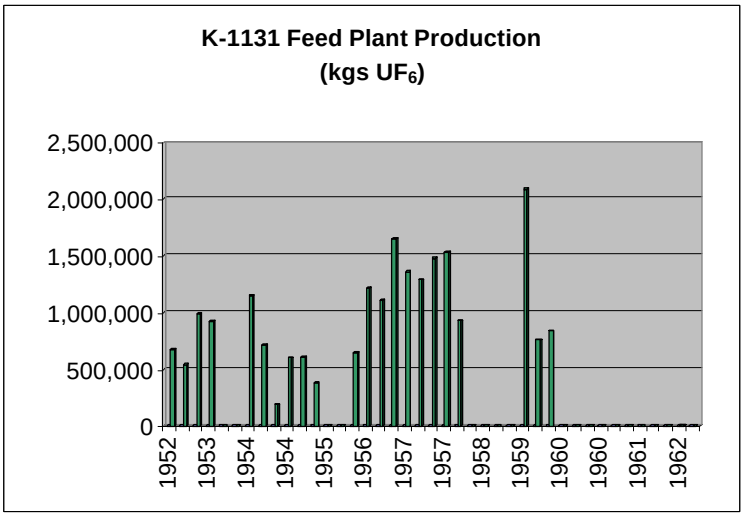


Fig. 2.2-2. K-1131 Feed Plant Production

Beginning in 1960 (or possibly earlier), as a part of its ORGDP decontamination and uranium operations, Building K-1420 also accepted oxides for processing from off-site sources, including Hanford and Savannah River. The K-1420 processing included fluorination to UF_6 and associated ash recovery and disposal operations. Building K-1131 was decommissioned during the late 1990s.

2.2.2 Feed Input

In the enrichment process, 2.5-, 10-, and 14-ton cylinders of UF_6 coming from one of the ORGDP feed production facilities [K-1131 (until 1961) or K-1420] or from off site were placed in large steam-heated autoclaves. The autoclaves were used to liquefy the feed UF_6 to allow efficient generation of UF_6 vapor for feeding to the cascade. Beginning in 1952, UF_6 feed was delivered to one of three feed facilities located in either K-131, K-33 feed room, or K-1131. The feed facilities in turn fed various stages in the cascade, typically including units in buildings K-27, K-29, K-31, and K-33. Both the UF_6 feed building and feed point varied over time.

2.2.3 Cascade Operation

In the enrichment process, gaseous UF_6 diffuses through a porous barrier containing millions of holes, each smaller than two-millionths of an inch. Because of the molecular weight difference between $^{235}UF_6$ and $^{238}UF_6$, slightly more ^{235}U atoms diffuse through the barrier than ^{238}U atoms. The slightly enriched UF_6 goes up the cascade where the process is repeated thousands of times to reach the desired product enrichment. UF_6 depleted in ^{235}U atoms goes down the cascade where it is eventually removed as depleted UF_6 (commonly called “tails”) from the cascade. The actual location in the cascade where feed is introduced into the cascade is

[1] *ORGDP Quarterly Reports*, 1952 to 1963

the "feed point," which varied depending on the enrichment of the UF_6 feed and how the cascade was configured. These feed points are described in Section 2.2.2.

ORGDP started with a single processing building, K-25, and at its peak had five large processing buildings operating together as a UF_6 enrichment cascade. Each of the buildings was broken down into sections, and each section was broken down into cells. The cells were in turn broken down into stages where the actual enrichment process occurred. Each stage consisted of a converter vessel, a gas compressor, a motor, a control valve system and associated piping.

Converters (Fig. 2.2-3) contained the barrier material and a gas cooler or heat exchanger to control the stage temperature. Compressors were used to pump the UF_6 gas through the barrier at optimum conditions. For maintenance, large block valves were used between successive groups of eight to ten stages to allow isolation of the equipment from the rest of the operating cascade. There were also the CIP/CUP major equipment upgrades in the 1970s, when, for practical purposes, the cascade was "rebuilt." Of course, significant auxiliary systems were required to operate the cascade (such as the power generation and distribution system and the cooling towers to dissipate waste process heat).

Fig. 2.2-3. ORGDP Converters

The cascade had side and top purge cascades. The purpose of the side purge was for the removal of intermediate molecular weight gasses, such as coolant vapor and chlorine fluorides. The top purge was used to remove the lighter gasses from the cascade.

2.2.4 Tails Withdrawal

As previously described, UF_6 depleted in ^{235}U atoms went down the cascade where it was eventually removed as tails from the cascade. The UF_6 tails were placed in large steel cylinders, cooled, and placed in various tails storage yards, K-1066A through L, at ORGDP for long-term storage. For the period of concern (after RU was first fed to ORGDP) tails were withdrawn from one of two locations in the cascade, Building K-601 and Building K-1131.

2.2.5 Product Withdrawal

Beginning in 1953 (when RU was first introduced into the cascade), the UF_6 top product was withdrawn from the K-25 building (at locations K-306-7, K-305-12, and K-305-1 through K-305-9). The UF_6 at enrichments up to 93% ^{235}U was placed in 5-in. cylinders and stored in cages on the operating floor near where it was withdrawn from the cascade until shipment to Y-12. After the K-25 high enrichment building was shut down, the assay of the top product was lowered to <5 wt % ^{235}U. This product was withdrawn in K-29 (at location K-502).

Beginning in 1969, DOE predecessor agencies began offering toll enrichment services for use by nuclear utilities in the United States and abroad. For a fee, customers provided natural

UF_6 feed and took enriched UF_6 product at assays typically in the range of 2 to 4 wt % ^{235}U. Product was withdrawn at the point in the cascade corresponding to the desired product enrichment. The UF_6 was withdrawn into large cylinders and was later transferred to 2.5-ton cylinders at Building K-1423 for delivery to commercial nuclear fuel fabricators.

2.2.6 Support Operations

During the life of ORGDP, many support operations were necessary. The principal on-site support operations that were involved with and were possibly impacted by RU streams are discussed in the following sections.

2.2.6.1 Decontamination and Uranium Recovery in Building K-1420 and Related Facilities

A key facility for supporting on-site operations and maintenance by providing radiological decontamination and uranium recovery was Building K-1420 (Fig. 2.2-4). This facility was designed and built in 1954 and utilized throughout the operational life of ORGDP. Equipment from every process building, except the feed building K-1131, was decontaminated and serviced in this facility. During the 1970s, Building K-1420 was upgraded and used for decontamination of major gaseous diffusion equipment being upgraded as part of CIP/CUP. Process facilities in K-1420 included equipment for converter conditioning and recovery, mercury recovery, Miller's fluorinated lubricating oil reclamation, classified parts disassembly and cleaning, cascade process equipment cleaning and decontamination, uranium recovery (including fluorination), and laboratory functions. K-1303, a smaller building, was used in the late 1940s and early 1950s before K-1420 was placed in service for activities involving decontamination of enrichment process equipment from Building K-25 and recovery of fluorinated lubricating oil.

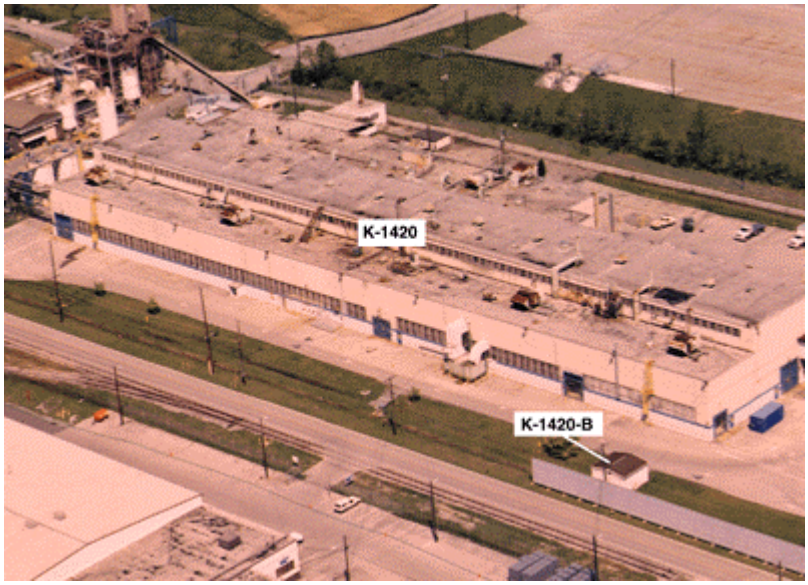


Fig. 2.2-4. Building K-1420 Exterior.

Following disassembly and/or decontamination activities, decontamination solutions were processed in K-1420 to recover the uranium. Aqueous waste effluents from the various chemical recovery operations were pumped to the K-1407-A Neutralization Pit and on to the K-1407-B Holding Pond. Later, contaminated sludge was dredged from K-1407-B and stored in the K-1407-C retention basin. In 1988, sludge was removed from the K-1407-B and K-1407-C ponds and either fixed in concrete or stored as wet sludge in 85-gal drums in an open storage yard adjacent to K-1417. In later years, effluents from K-1420 operations were discharged to the Central Neutralization Facility for pH adjustment, filtration, and release to Poplar Creek under NPDES permit.

Prior to 1976, discarded contaminated diffusion plant equipment and sensitive process components disassembled in K-1420 were likely buried in the classified burial ground located between Building K-25 and the K-1407-B Pond.

In 1961, K-1131 feed plant operations ceased, and K-1420, in addition to other activities, initiated limited feed plant capabilities. Major equipment in the uranium recovery system was designed to recover and concentrate uranium from liquid wastes generated by decontamination systems, enrichment process gas traps, and laboratory operations. The system produced uranyl nitrate that was converted to uranium oxides. The uranium oxide (or UF_4 from building K-1131) was converted to UF_6 feed. It is also known that various uranium materials from offsite were converted to UF_6 in K-1420. The feed was delivered to a flame tower reactor where fluorine was introduced. The resulting fluorination reaction produced UF_6, which was filtered and collected in cold traps.

K-1420 operations also involved removing heels from UF_6 cylinders, cleaning the cylinders, and processing the heels material. It is unclear whether this activity included recovering heels from feed cylinders.

2.2.6.2 K-1410 Decontamination and Uranium Recovery

Building K-1410 was built in 1944 and operated through 1979. For many years this facility was used for receiving, emptying, and refilling spent chemical traps from the K-25 building. Records show that from 1946 to 1962, K-1420 was used exclusively for decontamination and maintenance of uranium-contaminated feed plant equipment from K-1131 and for recovery of uranium from feed plant ash (see also Section 2.2.1 concerning treatment of ash in Building K-1231). Filtered process equipment wash water was discharged directly to Poplar Creek. Contaminated sludges, residues, oil, rags, and spent chemical trap media, as well as contaminated UF_6 cylinders were buried in the K-33 contaminated waste burial ground located northwest of building K-33. Building K-1031, located adjacent to K-1410, was used as a general storage area for the chemical operations conducted in K-1410. During 1963-1979, the building was used for nickel plating and now is generally referred to as the K-1410 Plating Facility.

2.2.6.3 K-770 Scrap Metal Yard

The K-770 Scrap Metal Yard is in the former ORGDP powerhouse area on the east bank of the Clinch River, upstream of the confluence of Popular Creek. It was originally built in the 1940s for the storage of fuel oil in a tank farm. Scrap metal storage began in the 1960s. The scrap includes various metals from equipment used at ORGDP and is contaminated with radioactive materials, including uranium and ^{99}Tc. The scrap metal inventory has been sorted according to metal type and size reduced. At least one on-site campaign was conducted several years ago to demonstrate recycle potential by smelting different types of scrap.

2.2.6.4 K-1401-N Converter Re-Tubing Area

During the 1970s, Building K-1401-N was constructed to support the CIP program. Facilities were provided to install, test, and assemble barrier in process converters. In other parts of the building, other process equipment from the cascade (i.e. UF_6 compressors and process valves) was refurbished. The process equipment was generally decontaminated in K-1420 prior to being transferred to K-1410. However, some chemical cleaning was conducted in K-1401,

consequently, chemical and radiological contamination may be present. Corrosive solutions used to clean equipment were transferred to the K-1407-A Neutralization Facility for disposal.

2.2.6.5 K-1421 Incinerator

The K-1421 Incinerator was operated from the mid-1950s until circa 1986. There were ugrades to the facility over time to meet changing performance and environmental standards. The incinerator was used to burn low-level contaminated combustible waste such as gloves, coveralls, wood, paper, plastic, and waste oil sludge. The incinerator was in an area of high radioactive contamination. There are reports that floor drains connected to either the K-1407-A Neutralization Pit or the K-1407-B Holding Pond. Low level contaminated ash was collected for uranium recovery at K-1420.

2.3 CONCENTRATING PROCESSES

2.3.1 Feed Operations

At the K-1131 feed plant (and later K-1420), when RU feed was fluorinated in the flame tower from UF_4 to UF_6, most of the Pu and a smaller fraction of the Np components contained in the RU were largely converted to relatively involatile compounds. These compounds were concentrated in the ash collected on the reactor off-gas filters and in the bottom of the flame tower. On the other hand, only a small percentage of the ^{99}Tc formed involatile compounds and stayed in the ash, while the balance of the RU ^{99}Tc was fluorinated as a volatile specie and collected overhead with the uranium.

Because Pu and Np were concentrated in the ash, the operations of removing, recycling, and packaging ash from the reactor and cleaning filters presented a significant potential for worker exposure. Periodically, personnel in breathing apparatus disconnected the filter and ash collectors, emptied the ash collectors, and replaced the filters.

Although the majority of the TRU elements went into the ash and filters associated with the fluorination operation, smaller quantities of Pu and Np, plus the majority of the ^{99}Tc, remained with the UF_6 and was collected in feed cylinders. Both PuF_6 and NpF_6 are slightly more reactive with the steel walls of the feed cylinder relative to UF_6, forming less volatile compounds that tended to stay in the feed cylinders during the subsequent UF_6 vapor feed operation.

After UF_6 was vaporized and was fed to the cascade, small quantities of uranium and any nonvolatile materials remained in the UF_6 feed cylinders. This material is referred to as cylinder heels. The nonvolatile material contained small quantities of Pu, Np, and ^{99}Tc. The emptied cylinders may have been refilled without heels removal, reused elsewhere in the ORGDP cascade, or sent to PGDP. The cylinders with heels may have been buried as contaminated waste or sent to Building K-1420 for cylinder cleaning and uranium recovery. However, former ORGDP employees familiar with K-1420 operations stated in discussions with members of the Site Team that they did not recall washing feed cylinders at K-1420 during the time RU was being processed. Only 2.5-ton cylinders that were used by the fuel fabricators in the commercial sector were washed at K-1420. Records concerning the disposition of ORGDP feed cylinder heels are incomplete.

2.3.2 Cascade

Minute quantities of Pu and small but measurable amounts of volatile Np and ^{99}Tc compounds were introduced into the cascade via the UF_6 feed stream. Residual amounts of Pu and Np fed to the cascade would have been removed from the feed stream by the barrier and other metal surfaces as solid deposits in the process equipment near the feed points. Most of the contaminated equipment would likely have been removed during the CIP/CUP efforts. Nickel removed from the barrier was smelted in a facility in K-1037 and shipped to PGDP.

^{99}Tc chemistry is considerably more complex than uranium or the TRU compounds. Multiple fluoride and oxyfluoride ^{99}Tc compounds are likely under the widely varying operating conditions of the cascade. Because of its lower molecular weight, any volatile ^{99}Tc compounds would tend to migrate up the cascade. Less volatile compounds accumulated as various surface deposits in the upper stages of the plant. The ^{99}Tc solids tended to redistribute in the process equipment as temperature and gas composition changes were made to optimize the enrichment stages. At ORGDP, the purge unit was above the product withdrawal point, and the purge unit had a ^{99}Tc trapping system.

2.3.3 Tails

It is possible, but not believed to be likely, that tails withdrawn from the cascade and placed in cylinders for long-term storage may have contained very small to negligible quantities of Pu, Np, and ^{99}Tc. The vast majority of the tails produced over the lifetime of the plant remain in storage, as previously described. Because there is a DOE program in progress to consider ways to beneficially use the depleted uranium, there is a need for a good understanding of tails contamination levels.

2.3.4 Product

HEU produced at K-25 during the period of time when RU was being fed to the cascade was shipped to the Y-12 Plant. The UF_6 product may have contained very small to negligible amounts of Pu and Np. Measurable quantities of ^{99}Tc are possible in the HEU product because ^{99}Tc was present in larger quantities in the UF_6 feed and volatile compounds (i.e., TcF_6 and TcO_3F) are not as reactive as the TRU compounds.

Low-assay product was shipped to fuel fabricators to produce commercial nuclear fuel. There was an American Society for Testing and Materials (ASTM) specification that was used for this product. This UF_6 was withdrawn at a lower enrichment point in the cascade than the HEU. The low-assay product may also have contained very small to negligible quantities of ^{99}Tc. Measurable quantities of Pu or Np are unlikely to have been present.

2.3.5 Support Operations

Support operations, especially those involving equipment maintenance and/or decontamination, would have presented the more significant scenarios for possible worker exposure to RU constituents. In particular, maintenance work associated with the fluorination tower reactor, ash collection, and solid transfer equipment would have offered the greatest opportunity for personnel exposure to Pu and Np. By their very nature, decontamination operations may have resulted in the removal and concentration of Pu, Np, and ^{99}Tc. Depending

on the operation and the material, solution, equipment, or waste involved, personnel performing support work in K-1420, K-1421, K-1410, and K-1303 would have experienced increased potential for exposure.

Uranium recovery and waste processing operations could have involved exposure to two different sources of concentrated ^{99}Tc. When the purge gases flowed through the chemical traps prior to venting, ^{99}Tc concentrated in the reactive NaF and MgF_2 media. Personnel collecting and emptying the traps and disposing of the waste solvent would have experienced increased potential for exposure. Also, personnel doing maintenance work associated with the upper cascade enrichment stages, including the purge cascade would have increased potential for exposure to ^{99}Tc.

Solvent extraction activities in K-1420 for uranium recovery also resulted in the concentration of ^{99}Tc in the raffinate stream and in sludge formed from raffinate treatment. From K-1420, this sludge was sent to the K-1407-A Neutralization Pit. The K-1407-B holding pond was used as a settling basin for metal hydroxide sludge precipitated after neutralization in the K-1407-A pit. The aqueous contents of K-1407-B were at times discharged to Poplar Creek. Sludge was also dredged from K-1407-B and stored in the K-1407-C retention basin. All sludge from both K-1407-B and K-1407-C was eventually dredged and stored, and both facilities were filled, capped, seeded, and posted as underground radioactive contamination areas. The personnel performing the sludge removal work may have been exposed to higher levels of ^{99}Tc and possibly traces of Pu and Np.

2.4 ACTIVITIES WHERE WORKERS WERE LIKELY TO BE IN CONTACT WITH RU THROUGH DIRECT PHYSICAL CONTACT OR AIRBORNE DUST

In its review of ORGDP facilities and processes, the ORGDP Site Team identified a number of activities that, based on available data, would be expected to present the greatest potential for workers to be exposed to the RU constituents of interest. Table 2.4-1 presents a list of these activities and the locations in which they occurred, along with the time frame, constituent level, and level of occupational exposure potential. In the table, activities are grouped by four major categories: (1) oxide conversion for UF_6 feed, (2) cascade buildings and operations, (3) uranium recovery operations, and (4) analytical laboratory analysis.

A discussion of the methodology used to perform constituent level calculations and to develop the ratings for the category "Occupational Exposure Potential" in Table 2.4-1 is provided in Appendix A.

Table 2.4-1. Activities Involving Potential Worker Exposure

Location	Activity	Time Frame	Constituents	Occupational Exposure Potential
	1. Oxide Conversion			
K-1131 K-1420	1A. Unpacking, feeding of UO_3 to process, operation and pulling samples * Exposure potential would have been high for brief periods in Jan-Apr 1953 when Pu ranged as high as 40 ppb in material from Hanford	1952-1961 1960-1963	Estimated levels in UO_3 520 ppb Np 4.4 ppb Pu 7,800 ppb Tc 170 ppm ^{236}U	Moderate*

Location	Activity	Time Frame	Constituents	Occupational Exposure Potential
K-1131 K-1420	1B. Collecting ash for uranium recovery and cleaning of tower filters	1952-1961 1960-1963	Estimated levels in ash 13,000 ppb Np 440 ppb Pu 40,000 ppb Tc 170 ppm ^{236}U	High
K-1231 K-1410	1C. U recovery from ash, processes included ash pulverizer	1952-1963 1952-1962	Estimated levels in ash 13,000 ppb Np 440 ppb Pu 40,000 ppb Tc 170 ppm ^{236}U	High
K-1131 K-1410	1D. Maintenance and repair of fluorination tower and associated equipment	1952-1961 1952-1962	Estimated levels 13,000 ppb Np 440 ppb Pu 40,000 ppb Tc 170 ppm ^{236}U	High
	2. Cascade Buildings and Operations			
Cascade feed points	2A. Feeding UF_6 from cylinder to the cascade	1952-1985	Estimated levels in UF_6 130 ppb Np 0.004 ppb Pu 6,600 ppb Tc 170 ppm ^{236}U	Moderate
Cascade buildings	2B. Inadvertent releases of UF_6 within cascade buildings or from piping between cascade buildings	1952-1985	Estimated levels in UF_6 31 ppb Np 0.001 ppb Pu 2,300 ppb Tc 87 ppm ^{236}U	Moderate
Product withdrawal points	2C. Withdrawal of product from cascade into cylinders	1952-1985	Estimated levels in UF_6 <5 ppb Np 0 ppb Pu 1,800 ppb Tc 395 ppm ^{236}U	No significant
Tails withdrawal points	2D. Withdrawal of tails from cascade into cylinders	1952-1985	Estimated levels in UF_6 0 ppb Np 0 ppb Pu 0 ppb Tc 40 ppm ^{236}U	No significant
Cascade purge locations	2E. Venting process gas to atmosphere from operating cascade through process stack	1952-1985	Estimated levels in UF_6 <5 ppb Np 0 ppb Pu 2x10^{7}ppb Tc 400 ppm ^{236}U	Moderate
Cascade feed points	2F. CIP/CUP and other work involving removal of converters, compressors, and valves associated with cascade feed points	1952-1985	Estimated levels 130,000 ppb Np 4 ppb Pu 1,000 ppb Tc 170 ppm ^{236}U	Moderate
Cascade purge locations	2G. CIP/CUP and other work involving removal of converters and compressors, and valves associated with the purge cascade	1952-1985	Estimated levels <5 ppb Np 0 ppb Pu 7,500 ppb Tc 395 ppm ^{236}U	Moderate

Location	Activity	Time Frame	Constituents	Occupational Exposure Potential
Cascade buildings	2H. CIP/CUP and other work involving equipment removal and maintenance activities other than near feed point or purge cascade	1952-1985	Estimated levels <5 ppb Np 0 ppb Pu <1,000 ppb Tc 100 ppm ^{236}U	No significant
	3. Recovery Operations			
K-1410 K-1420	3A. Cleaning of heels from UF_6 cylinders	1955-1979 1954-1993	Estimated levels in heels 26,000 ppb Np 4 ppb Pu 70,000 ppb Tc 170 ppm ^{236}U	Moderate
K-1303 K-1410 K-1420	3B. Decontamination of equipment associated with feed point and recovery of uranium	1952-1955 1952-1979 1954-1993	Estimated levels 130,000 ppb Np 4 ppb Pu 1,000 ppb Tc 170 ppm ^{236}U	Moderate
K-1303 K-1410 K-1420	3C. Decontamination of equipment associated with purge cascade and recovery of uranium	1952-1955 1952-1979 1954-1993	Estimated levels <5 ppb Np 0 ppb Pu 7,500 ppb Tc 395 ppm ^{236}U	Moderate
K-1303 K-1410 K-1420	3D. Decontamination of equipment associated with other than near feed point or purge cascade	1952-1955 1952-1979 1954-1993	Estimated levels <5 ppb Np 0 ppb Pu <1,000 ppb Tc 100 ppm ^{236}U	No significant
K-1037 K-1303 K-1410 K-1420 K-1421	3E. Uranium recovery from and/or processing of contaminated oils, cleaning solutions, and other wastes	1952-1981 1952-1955 1952-1979 1954-1993 1954-1986	Estimated levels in solutions <5 ppb Np 0 ppb Pu 1,000 ppb Tc 100 ppm ^{236}U	Moderate
K-770 Scrap Metal Yard	3F. Handling of scrap metal from equipment	1960s-present	Estimated levels on metal 0 ppb Np 0 ppb Pu 1,000 ppb Tc 100 ppm ^{236}U	Low
K-1407-B K-1407-C K-1419	3G. Removal, transfer, and/or storage of sludge from facility treating constituents concentrated in sludge	1952-1988 1973-1988 1987-1988	Estimated levels in sludge 2 ppb Np 0.02 ppb Pu 41,000 ppb Tc 100 ppm ^{236}U	Moderate
RUBB Buildings	3H. Thermal drying/repackaging of pond sludge for offsite disposal	1991-1992	Estimated levels in deposits 2 ppb Np 0.02 ppb Pu 200 ppm Tc 100 ppm ^{236}U	Moderate

Location	Activity	Time Frame	Constituents	Occupational Exposure Potential
Cascade buildings and associated piping	3I. Recovery of uranium deposits from process equipment associated with cascade feed points following shutdown of ORGDP	1987-present	Estimated levels on metal 130,000 ppb Np 4 ppb Pu 1,000 ppb Tc 170 ppm ^{236}U	Moderate
Cascade buildings and associated piping	3J. Recovery of uranium deposits from process equipment associated with purge cascade following shutdown of ORGDP	1987-present	Estimated levels in traps <5 ppb Np 0 ppb Pu 7,500 ppb Tc 395 ppm ^{236}U	Moderate
Cascade buildings and associated piping	3K. Recovery of uranium deposits from process equipment other than feed points and cascade purge following shutdown of ORGDP	1987-present	Estimated levels in traps <5 ppb Np 0 ppb Pu 1,000 ppb Tc 100 ppm ^{236}U	No significant
K-1031 K-1410 K-1420	3L. Service cascade chemical traps	1952-1962 1952-1962 1960-1985	Estimated levels in traps 5 ppb Np 0 ppb Pu $1x10^8$ ppb Tc 395 ppm ^{236}U	Moderate
	4. Analytical Labs			
Analytical laboratories K-1004A, B, C, D, J K-1006	4A. Analytical laboratory sampling	1952-1985	Estimated levels in samples 13,000 ppb Np 440 ppb Pu 40,000 ppb Tc <395 ppm ^{236}U	No significant

2.4.1 Descriptions of Activities Presenting Occupational Exposure Potential

The following sections provide more information on the activities listed in Table 2.4-1. For ease of correlation with the information in Table 2.4-1, the same alphanumeric system used to group activities in the table (i.e., 1A, 1B, etc.) is employed for these next sections

1. Oxide Conversion for UF_6 Feed

1A. Unpacking, Feeding, and Sampling of UO_3

Oxide in the form of UO_3 was delivered to the K-1131 feed plant in hoppers. (K-1420 also had oxide conversion capabilities—initially to recover enriched uranium from decontamination solutions. K-1420 subsequently received and converted RU oxide for use as feed, but on a much smaller scale than K-1131.) The UO_3 powder was fed directly into sequential reactors and hoppers to achieve conversion to UF_6. The design of the UO_3 hoppers featured a heavy steel frame that supported a box-like container with a funneled bottom. The hoppers arrived funnel

up, with a flanged cover on the funnel end. This cover was replaced with a flapper valve assembly before the hopper was inverted into the feed position. The inverted hopper was placed on the feed point of the conversion system, and the valve was opened to permit material transfer. Although the oxide was in powder form, because of the particle size and density, the potential for the oxide to become airborne was not high. The resulting hazard was thus determined to have a "Moderate" occupational exposure potential. However, in the period of January 1953 through April 1953, receipts were recorded for shipments of oxide from Hanford containing up to 40 ppb of Pu (a significantly higher level than noted for receipts during any other time). At that level, the occupational exposure potential would be rated "High" for that relatively short period of time.

1B. Collecting Ash and Cleaning Tower Filters

In the UF_4 to UF_6 conversion step, any unreacted or partially converted residual uranium solids (referred to as ash) were collected in a receiver can located below the fluorination reactor. The ash container, which was approximately 2 ft in diameter, with a capacity of approximately 30 gal, was exchanged as a routine part of operations. Ash also collected on the tower reactor filters, which carried similar exposure potential. Because of the increased concentrations of Pu and Np in this material and the inherent potential of the fine ash to become airborne, ash provided one of the more significant pathways for worker exposure during these operations. The potential for any loose ash to become airborne or spilled represented a "High" exposure potential for the employee because of the constituent levels (concentrated transuranics with some fission product), the nature of the ash collection process, the physical properties of the ash, and the frequency with which these operations had to be performed.

1C. Uranium Recovery from Ash

During the earlier part of ORGDP's operating history, the shortage of uranium feed and the poor reactivity of the RU feed made it desirable to recover the uranium value in ash from the UF_4 to UF_6 conversion process. In an attempt to recover essentially all of the uranium, the ash was collected, pulverized, and re-fed through the conversion process. When beneficial reclamation of the uranium from the ash was no longer feasible, the residual ash was containerized and stored. Most of the spent ash (which contained approximately 99% of the incoming Pu, 25% of the incoming Np, and 5% of the incoming ^{99}Tc) was eventually shipped to PGDP. As with ash collection and filter cleaning activities, the exposure potential associated with manual operations for recovering uranium from ash was determined to be "High."

1D. Maintenance and Repair of Fluorination Tower

Maintenance and repair activities occasionally associated with the fluorination tower carried considerable potential for worker exposure to finely divided uranium solids concentrated in Np and Pu. Equipment failures or breakdowns often necessitated the disassembly of equipment containing significant quantities of in-process material. The tower reactor for UF_4-to-UF_6 conversion would sometimes plug, requiring mechanical disassembly and potential exposure to solids for personnel manually removing the obstructions. Feed screws would sometimes jam with uranium slag and require similar remedial actions. In addition, the UF_6 gas would also sometimes freeze in the outlet line and need to be manually cleared. Although these activities

occurred less frequently than handling the ash receiver, their nature contributed substantially to the potential for exposure. As a result, the occupational exposure potential was determined to be "High."

2. Cascade Buildings and Operations

2A. Feeding UF_6 from Cylinders to Cascade

Although the majority of incoming ^{99}Tc entered UF_6 feed cylinders with the UF_6 produced at a feed plant, only a small fraction of Np and an even smaller fraction of Pu entered into the feed cylinders. In the feed process, the UF_6 cylinder was placed into a large autoclave to liquefy the UF_6 contents under its own vapor pressure and promote efficient high volume vapor transfer to the cascade. Beginning in 1952 (which was when RU was first introduced into the ORGDP cascade in production quantities), UF_6 feed was delivered to the cascade in various years from one of three buildings (K-131, K-33 Feed Room, or K-1131). The feed buildings fed to various stages of the cascade—depending on the cascade configuration—but typically including cells in buildings K-27, K-29, K-31 and K-33. UF_6 and all of the various minor volatile metal fluorides present in the feed cylinder had a tendency to react with the cylinder wall steel to form non-volatile reduced metal fluorides. PuF_6 is the most reactive (i.e., most easily reduced) of the feed components while UF_6 is the least reactive. Because of the higher reactivity of PuF_6 and NpF_6, essentially all of the Pu and much of the Np remained in the empty feed cylinder as non-volatile fluorides as the uranium was removed. Although the constituent levels and potential for becoming airborne were appreciable, the duration of the physical activities associated with the UF_6 feed operation was very brief. Potential for exposure existed only when process feed line connections were being made or broken. Consequently, the exposure potential was judged to be only "Moderate."

2B. Inadvertent Releases of UF_6 within Cascade Buildings or from Piping

Although not routine, releases in the process equipment and/or associated piping and cascade instrumentation were not uncommon. Based solely on the constituent level, the potential for exposure could be significant. However, because the cascade was operated at pressures below atmospheric, the potential for airborne hazards was low. Breaches in the system resulted in an inflow of ambient air rather than a release of process gas into the building. Furthermore, the duration of such an event would be very short, as it would be obvious to the control room personnel and would result in prompt reconfiguration of the affected cell to isolate it from continued gas flow. The exposure potential associated with releases from the diffusion cascade was rated as "Moderate."

2C. Product Withdrawal

All of the PuF_6 and most of the NpF_6 entering the diffusion cascade with the UF_6 feed gas was rapidly reduced by the active metal surfaces of the cascade and immobilized in the feed gas piping and converters as non-volatile fluorides. These compounds tended to accumulate around the cascade feed points. Most of the ^{99}Tc proceeded up the cascade with the enriched UF_6. The ORGDP cascades were always operated with the benefit of a purge cascade, which served to remove light gases (air and nitrogen seal gases) and intermediate molecular weight gases

(Freon 114 and various fluorination gases) to promote efficient collection of enriched UF_6 product. UF_6 was extracted at various points in the cascade below the top purge units for light gases and downstream of the side purge equipment for intermediate gases. ^{99}Tc tended to collect between the top purge and the UF_6 product withdrawal point as an intermediate molecular weight gas. Some ^{99}Tc was vented to the atmosphere with the light gases, and some was withdrawn with the UF_6 product. But the majority of the ^{99}Tc tended to accumulate in the purge cascade equipment. However, the product was relatively free of any transuranic compounds. The potential exposure duration to the cascade product was very brief and only existed when connections were being made or broken. As a result, the exposure potential was rated as "No Significant" potential.

2D. Tails Withdrawal

As the ORGDP cascade configuration changed throughout the history of the plant, the feed point was moved to various locations. In all instances, however, tails were withdrawn at a point well below the feed point. Because Np and Pu were primarily retained on the surfaces of the equipment at the feed points and ^{99}Tc migrated upstream, the tails were relatively free of RU constituents. In addition, the potential exposure duration was very brief because the potential only existed when process gas connections were being made or broken. The exposure potential was thus rated "No Significant" potential.

2E. Venting Process Gas to Atmosphere

Gas exhaust from the ORGDP cascade was ultimately vented to the atmosphere. The purge cascade design and operating parameters caused any UF_6 that entered the side or the top purge cascade to be rejected downstream and separated from the vent gases. Because Pu and Np plated out on equipment near the feed point, they were not significant constituents in the vent gases. Depending on the operating profile of the cascade, however, some ^{99}Tc passed through the purge cascade and was vented to the environment. The balance of the ^{99}Tc tended to collect in the purge equipment. In the early 1960s, chemical traps were placed at the top of the purge cascade to minimize ^{99}Tc emissions. (Prior to that time, some fraction of the total ^{99}Tc fed to the enrichment plant was vented.) The efficiency of the trap (typically around 80%) was very dependent on routine maintenance and change-out. Records indicate that this maintenance program was marginal at times. As a result, ^{99}Tc was vented throughout the operation of the cascade, but to a lesser extent after the early 1960s. Certainly, the ^{99}Tc constituent level in the diffusion plant exhaust was significant at times, and airborne potential was high under these circumstances, as the most likely ^{99}Tc species (TcO_3F and TcF_6) were volatile at discharge. The exposure duration, however, would be very brief. The process stack was well above the roof of the cascade buildings and removed from normal personnel traffic—thus minimizing the possibility of workers being directly exposed to the vent gases. The exposure potential was calculated to be "Moderate."

2F. CIP/CUP and Other Equipment Removal at Feed Points

Process equipment throughout the ORGDP cascade routinely required maintenance and repair. If this work involved the converter, compressor, or valve components near the feed points, workers were likely to encounter Pu and Np solid deposits or, possibly, dust. Typically,

contaminated equipment was removed from the cascade, openings were covered in the field, and the equipment was transported to a decontamination facility as a precursor to working on the component. Seal replacement was performed in the field, but repair/replacement was typically accomplished as an enclosed package and not as components. In addition to removing equipment for routine maintenance, ORGDP implemented two major upgrade programs during the late 1970s: the Cascade Improvement Program (CIP) and the Cascade Upgrade Program (CUP). Together, these two programs constituted a virtual rebuilding of the cascade. Although workers likely encountered Pu and Np when working near the feed points in such operations, the actual duration of exposure at these locations would be expected to have been relatively low. Accordingly, the exposure potential for these activities was determined to be "Moderate."

2G. CIP/CUP and Other Equipment Removal at Purge Cascade

Workers removing converter, compressor, or valve components in the various purge areas of the cascade for CIP/CUP or routine maintenance or repair were likely to encounter ^{99}Tc. However, the actual duration of exposure during field removals at these locations would be expected to have been relatively low. Thus, the exposure potential for these activities was determined to be "Moderate."

2H. CIP/CUP and Other Equipment Removal at Other Points

Workers removing converter, compressor, or valve components for CIP/CUP or routine maintenance or repair in areas of the cascade other than near the feed points or the purge areas were unlikely to encounter significant quantities of the RU constituents of concern. Because Pu and Np were basically concentrated near the feed points and ^{99}Tc was concentrated at the purge areas, these constituents posed little or no hazard at other locations in the cascade. Workers would be expected to encounter only uranium residues. Therefore, the exposure potential for this activity was rated "No Significant" potential.

3. Uranium Recovery Operations

3A. Cleaning Heels from UF_6 Feed Cylinders

Some cleaning of heels from potentially RU-contaminated feed cylinders may have taken place at ORGDP. (Records regarding ORGDP feed cylinder heels are incomplete.) Because uranium compounds are water-soluble, the cylinder cleaning was typically accomplished by rinsing with water. Pu and Np formed compounds that reacted with the steel cylinder walls upon contact and were not as water-soluble as the uranium. These compounds were only partially removed when the cylinders were cleaned. Rinsing and spraying the cylinder with water had the advantage of entrapping the material and reducing the potential for it to become airborne. The airborne potential was judged to be moderate. Even with concentrations of transuranics and fission products in the heel of the cylinder, this activity was rated "Moderate" for exposure potential because of low exposure duration.

3B. Decontamination of Equipment from Feed Point

When ORGDP cascade process equipment was replaced or repaired as part of upgrade programs, such as CIP/CUP, or routine maintenance or repair, the equipment was decontaminated to protect workers and to recover uranium. Because decontamination work involved access to internal surfaces of the process equipment, there was potential for workers to be exposed to associated contamination. In decontaminating equipment from locations near the feed points (which varied over the life of the cascade), workers would have encountered elevated levels of Pu and Np. Because upgrade programs were extensive and continued over a number of years and maintenance and repair were ongoing, activities, the associated exposure duration would be expected to be significant. Consequently, the exposure potential was rated "Moderate."

3C. Decontamination of Equipment from Purge Cascade

In decontaminating equipment from the purge cascades (which varied over the life of the cascade) and chemical traps, workers would have encountered elevated levels of ^{99}Tc. Because upgrade programs were extensive and continued over a number of years and maintenance and repair were ongoing activities, the associated exposure duration would be expected to be significant. Consequently, the exposure potential was rated "Moderate."

3D. Decontamination of Equipment from Other Points

As noted in Sect. 2.4.4.2 and 2.4.4.3, workers decontaminating equipment as part of upgrade programs or routine maintenance or repair would have encountered elevated levels of Pu and Np in equipment from near the feed points and elevated levels of ^{99}Tc in equipment from the purge cascades and chemical traps. For work on equipment from locations other than these areas, the overall exposure potential is reduced significantly. Accordingly, the occupational exposure potential was determined to be “Low."

3E. Processing of Wastes for Uranium Recovery

During the earlier part of ORGDP’s operating history, the shortage of uranium feed made it desirable to recover the uranium value in decontamination solutions and other waste streams. As uranium became more plentiful, recovery efforts were reduced substantially and more uranium was discarded in various waste streams. Because recovery streams came from throughout the cascade, contamination by the RU constituents of concern was diluted. Oils were distributed from large reservoirs, and waste products such as paper and wipes were collected in gross quantities. Consequently, levels of RU constituents would have been expected to be low. As the waste streams tended to be liquid or wet, airborne potential would also have been low. However, because these activities were conducted routinely and on a large scale throughout the history of ORGDP cascade operations, the exposure duration would have been high. The exposure potential was thus rated "Moderate."

3F. Handling of Scrap Metal from Equipment

The decontamination of equipment being repaired or replaced typically resulted in the elimination of any loose surface contamination—leaving only residual amounts of fixed contamination on equipment. The scrap metals from equipment repairs and/or replacements were placed into the K-770 scrap metal yard on the ORGDP Site, where many metals remain today in contaminated storage. In addition, some metal was melted for volume reduction. Because of the removal and/or reduction of contamination, the elimination of loose material, and the level of activity for this type of work, the exposure potential was determined to be "Low".

3G. Removal and Storage of Pond Sludge

Spent solutions from ORGDP decontaminating processes were discharged into precipitation and holding ponds at the site. Several years after the shutdown of the ORGDP enrichment facilities, an effort was undertaken to dredge the sludge from these ponds, mix it with concrete, and place it into storage in large steel drums. During the end of that effort, however, many drums were filled with raw sludge without the concrete component. Although the level of constituents would have been appreciable, the form of the material was a true sludge with significant water content and little potential to become airborne. The exposure potential was rated as "Moderate."

3H. Thermal Drying and Repackaging of Pond Sludge

Raw pond sludge containing transuranics and fission products and stored in steel drums at ORGDP eventually corroded the drums and necessitated remedial action circa 1991–1992. The approach selected called for removing the sludge from the drums, thermally drying it, and repackaging it into new containers. Although the thermal drying operation provided significant potential for generating airborne hazards, the exposure duration was brief because of the short time frame of this effort. These factors, in combination with the sludge constituent levels, resulted in an exposure potential rating of "Moderate" for this activity.

3I. Recovery of Uranium Deposits Near Feed Points Following Shutdown

Years after the ORGDP cascades were shut down, concerns with criticality safety related to deposits of enriched uranium in the process equipment arose as the process buildings continued to age and became more susceptible to roof leaks. As a result, the Deposit Removal program was implemented to identify the location of the deposits, quantify the amounts and assays of the material, and remove those deposits that posed a significant criticality hazard. This material was placed into storage containers following removal.

During the CIP/CUP efforts, essentially all accumulations of Pu, Np, and ^{99}Tc in the cascade were removed from the converters and compressors as a result of the upgrade programs. Even constituents located in the piping and/or valves would have been reduced as a result of purge procedures performed prior to taking the equipment off-line for the upgrade work.

Post-CIP/CUP and until 1984, RU as UF_6 was received from PGDP and foreign sources and some was fed to the ORGDP. This material would have introduced small quantities of Np and ^{99}Tc into the cascade. Essentially all of the Pu and much of the Np would have remained in the

empty feed cylinder as non-volatile fluorides. The small quantities of Np that were fed to the cascade would have concentrated at the feed points and the ^{99}Tc would have proceeded up the cascade and concentrated around the purge equipment.

Information from the Deposit Removal Program indicates no significant issues with TRU or ^{99}Tc in the deposits. The nature of the work, which used manual and mechanical methods to remove and collect deposits, could have generated airborne material over the short period of time the operation was conducted. The exposure potential was determined to be “Moderate."

3J. Recovery of Uranium Deposits Near Purge Cascade Following Shutdown

As discussed previously, Pu and Np introduced into the cascade would have plated out near the feed points. Material near the purge cascade contained volatile and semi-volatile ^{99}Tc that had proceeded up the enrichment cascade and accumulated in the purge area. The ^{99}Tc would have presented some hazard during Deposit Removal activities performed in the area of the purge units. Given the fact that the Deposit Removal work had the potential for generating airborne material, the exposure potential was determined to be “Moderate."

3K. Recovery of Uranium Deposits from Other Points Following Shutdown

As noted in Sect. 2.4.4.9 and 2.4.4.10, workers performing Deposit Removal work following shutdown may have encountered low levels of Np and much lower levels of Pu near the feed points and elevated levels of ^{99}Tc near the purge cascades. For Deposit Removal work in locations other than these areas, the overall exposure potential was rated as “No Significant” potential.

3L. Service Cascade Chemical Traps

MgF_2 traps were used to capture and remove ^{99}Tc at the upper end of the cascade. ^{99}Tc also accumulated in NaF traps used to remove uranium from the side purge. Because of the nature of the sorbent material, the removal and replacement of the trap material was an operation that presented a high potential for material contaminated with ^{99}Tc to become airborne. Although the ^{99}Tc level and airborne potential were high, consideration of the infrequent performance of such operations resulted in an exposure potential rating of “Moderate."

4. Analytical Laboratory Analysis

Samples of oxide feed received at ORGDP were sent to the ORGDP analytical labs for analysis. These samples would have been containerized in lidded vials and carefully labeled with their origin. Typically, lab samples were in the range of a few grams and did not represent very large quantities of material. Once in the laboratory, samples were handled very carefully to preserve sample quality and prevent any cross contamination. Protocol for lab cleanliness and sample preservation was pristine. Although the samples had the potential to contain appreciable quantities of RU constituents, they were carefully handled within a ventilated laboratory hood. The exposure potential was thus rated as “No Significant” potential.

2.4.2 Worker Radiological Protection Programs

A search for documents that might provide information on the ORGDP worker protection program resulted in the discovery of several reports, audits, data summaries, and other documents. These materials provided a general summary of this ORGDP program for the time frame during which RU material was being processed. Based on the information reviewed, it is clear that receipt of RU was anticipated at the plant and that planning was accomplished to deal with the health and safety issues involved in processing this material. This RU awareness was confirmed in conversations with retired personnel who were directly involved in the operations and processes key to RU.

ORGDP monthly reports for Pu reported total U mg, total Pu mg, and ppb Pu/U.[2] Urinalysis data reporting Pu results were available from 1945 through the entire period of time RU material was processed. Sampling reports for K-1131 as early as 1953 also reported ppb Pu/U. It is not clear that Np or Tc were initially recognized as constituents.

A good deal of effort at ORGDP was spent on correlating surface contamination to potential airborne contamination in K-1131 based on data from 1957 through 1960. The 1960 report "Uranium Alpha Surface Contamination, Airborne and Urinary Excretion Rates" included urinalysis, air sampling, surface and respirator usage information.[3]

A document published in 1957 entitled "Radiation Protection Practices at the Oak Ridge Gaseous Plant"[4] provided an extensive summary of information on worker protection practices. The following sections summarize the contents of this document. The various program elements described were also present in the 1973 document *Nuclear Materials Management Manual*[5] that was reviewed as part of this effort.

2.4.2.1 Basic Plant Methods

The ORGDP Safety Program, of which the radiation-protection aspects of plant operation constituted a part, placed the primary responsibility for accident prevention on the line organization. Medical, health physics, and industrial hygiene staff groups were responsible for assisting in the evaluation of the potential hazards to personnel resulting from plant operations and for making appropriate recommendations to control those hazards. Service organizations and facilities were provided to assist the line and staff groups in meeting those responsibilities.

Plant acceptable limits for radiation and radioactive contamination levels, which were in accord with the recommendation of nationally recognized groups in that field, were established at values well below any known injury level for continuous personnel exposure, and efforts were made to prevent employee exposure to conditions exceeding those limits. The National Bureau of Standards Handbooks 59 and 69 offered criteria for penetrating and internal radiation exposures, respectively.

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[2] *Monthly Plutonium Report*, Union Carbide Nuclear Company, Oak Ridge Gaseous Diffusion Plant, 1953–1961.
[3] N. B. Schultz, et al., "Correlation of Uranium Alpha Surface Contamination, Air-Borne Concentrations, and Urinary Excretion Rates," KR-150, Union Carbide Nuclear Company, Oak Ridge Gaseous Diffusion Plant, June 22, 1961.
[4] H. F. Henry, et al., "Radiation Protection Practices at the Oak Ridge Gaseous Plant", KSA-81, Union Carbide Nuclear Company, Oak Ridge Gaseous Diffusion Plant, April 3, 1957.
[5] *Nuclear Materials Management Manual*, K-P-4086, Rev. 4, Union Carbide Nuclear Company, Oak Ridge Gaseous Diffusion Plant, 1973.

Personnel protective equipment was provided to employees as necessary, and adequate clinical facilities were available on-site. The evaluation of plant conditions and individual problems was based on thorough programs of clinical examinations and both personnel and environmental monitoring. The aid and advice of authorities in the field was made available as necessary or desirable.

2.4.2.2 Roles and Responsibilities

Responsibility for the protection of the employee against radiation health hazards rested with the line organization to the same extent that line organization personnel were responsible for operation and production. Supervisors formulated and administered rules and regulations for each area or major operation under their authority. Responsibilities included:

- Monitoring the extent and intensity of radiation or radioactive contamination in the work area.
- Providing employees with the appropriate personnel protective equipment and enforcing the use of that equipment.
- Establishing work-time limits on jobs with penetrating radiation.
- Decontaminating facilities in excess of Plant Action Level (PAL).
- Identifying/tagging contaminated equipment and facilities where radiation hazards were present.
- Reporting any new and/or potentially hazardous processes or materials to the Health and Safety staff groups.
- Maintaining a personnel monitoring program as necessary, making available hand-counting facilities and other radiation instruments, obtaining records of data from these devices, and initiating requests for provision of film badge and film ring monitoring services.
- Handling all cases of exposure in excess of the PAL, including accident reporting and investigation.
- Forwarding copies to the Safety, Fire and Radiation Control organization of established rules and regulations, surveys of hazards, personnel monitoring results, and information concerning radiation and radioactive contamination.

The employee was expected to follow rules and regulations pertaining to job hazards for his location and assignment, monitor his person and work area as required, and notify his immediate supervisor of any known exposure to radioactive materials or conditions exceeding the allowable radiation or contamination values.

Staff Groups were comprised of the Safety, Fire and Radiation Control Department and the Medical Department (which combined medical and industrial hygiene). Their responsibilities with regard to radioactive materials included the following functional activities:

- Evaluation of environmental health hazards and recommendation of the corresponding PAL values for personnel exposure.
- Independent monitoring and audit of facilities and equipment to determine the effectiveness of measures employed to control toxicological, contamination, and radiation hazards.
- Provision of film devices, processing those devices, and maintenance of personnel monitoring records.

- Treatment of occupational illnesses and injuries.
- Determination of clinical effects that might be related to exposure to radioactive and/or chemically toxic materials and recommending job placement of employees to avoid aggravation of pre-existing pathology.
- Maintaining liaison with authorities in the field and advising the line organization of new developments affecting PALs, improvements in detection methods or protective devices, and treatment of possible injuries/illnesses.
- Continual review of overall plant program and making recommendations to the line organization.

The Service Organizations included Plant Engineering, Shipping and Receiving, Stores, Tool Stores, Works laboratory, Decontaminating Agencies, Process Utilities, Instrument Maintenance and Laundry. Each of these disciplines provided service that was necessary in the daily routine of the operation.

2.4.2.3 Plant Limits

Plant Limits were established for internal exposure, alpha contamination (personnel and environmental), beta-gamma (external penetrating and contamination), and shipping contaminated materials.

Internal exposure specified the permissible body burden for continuous exposure to internal alpha emitters and included U-normal, ^{233}U, and ^{239}Pu, with limits given for soluble and insoluble forms. Excretion rate limits were also specified.

The alpha personnel contamination PAL was specified for masks and respirators (transferable and surface), hands, body, clothing, and shoes in dis/min/cm^2. The alpha environmental contamination PAL was provided for air and water in terms of uranium and plutonium. A Contamination Index was utilized for floors, tables, and other work surfaces. This index was an indicator that averaged the intensity of surface and transferable contamination over a given work location or surface area and under conditions where surface contamination might be a concern. This index was a measure of the relative hazard of various locations.

Beta-gamma external penetrating radiation limits were based upon the type of radiation and the particular body organ, and expressed as mr or mrep per 2-week badge period. The beta-gamma contamination PALs were specified for personnel contamination and for environmental conditions (air, surface, and water).

Acceptable activity levels were also defined for shipping non-contaminated material and contaminated scrap, which could be offered for public disposal, if the contamination did not exceed those values.

2.4.2.4 Plant Regulations and Practices

Personnel Practices. Employees working with radioactive materials were given complete examinations at the time of employment, at termination, and periodically during employment. They also received more frequent partial examinations, including blood counts and urinalysis. Employees working with plutonium-bearing materials (> 1 ppm Pu in U) were examined at least once every 6 weeks.

Health records, including exposure histories, were maintained as part of the complete plant exposure records. These records included the results from film badges, film rings, pocket

chambers and dosimeters, personnel involvement in releases of radioactive materials, the clinical results of that involvement, routine hand-counting results and hand/clothing spot checks. Medical advisory services were available to each employee.

Exposures to conditions in excess of the PAL were handled in accordance with plant procedures for the reporting and investigation of accidents. Measurements exceeding the PAL were determined by the results of shift length air samples, positive urinary findings, material releases, film meters (rings or badges), pocket chambers or dosimeters, or hand counts.

Radiation exposures (total body and hand) were reported for each two-week badge period. The values were compared to the respective PAL to determine any necessary follow-up. If the values were less than the PAL, no specific action was taken. Employees with results that exceeded the PAL by 10X were considered injured and were provided medical attention. Exposures that fell between the PAL and this higher limit resulted in work restrictions for the affected employee. During the restrictions, interim limits were set for the employee at less than half of the PAL. Restrictions remained in effect until the film badge results fell below the PAL, after which the employee could be returned to his previous assignment. If exposure results during the restriction exceeded the interim limits, the employee would be further restricted from any work involving penetrating radiation until the values fell below the PAL. In addition, a quarterly accumulated radiation exposure limit was also used for personnel monitoring and determining any associated work restrictions that might be necessary.

Urinalysis results that showed positive chemical values or alpha counts resulted with a recall for a follow-up submittal and analysis. Evidence of potential over-exposure resulted in the removal of the employee from contact with the radioactive materials until normal values were established. Additionally, four successive positive urinary values required obtaining a weekend sample (24 hours away from plant operations) to determine if radioactive materials were being stored in the body. Any evidence of detectable Pu or a significant fraction of the maximum permissible uranium body burden resulted in the removal of the employee from contact with such materials.

General Operational Practices. The confinement of radioactive contaminants within closed systems and shielding of penetrating radiation sources or fields to levels within the prescribed PAL was fundamental to control measures. As a result, design drawings for new facilities and modifications were forwarded to Staff and Service groups for formal comments. Field audits were made on a random basis to ensure that installations were made in accordance with those drawings.

Employees working with radioactive materials or in areas where it was not feasible to provide design features to prevent possible exposures were provided with personnel protective equipment (PPE) and protective devices as necessary. They were instructed in the hazards that might be encountered, and specific administrative controls were designed by the line organization to provide adequate protection.

The spread of radioactive materials was minimized by the decontamination of areas and equipment and through process design that included measures such as stainless-steel wall sheets, catch pans, strippable coatings, and vent hoods/booths. In addition, change facilities were provided that afforded separate storage for company issued clothing/PPE (that might be contaminated) from the employees' personal clothes. Good housekeeping was also emphasized as a daily measure to avoid the spread of contamination and included routine monitoring as a guide for decontamination efforts.

Work Involving Contamination and Radiation. The inhalation of radioactive materials was recognized as the most important source of possible exposure at ORGDP and, consequently, administrative controls were designed primarily to prevent this from occurring.

When attempts to maintain the alpha airborne contamination below the PAL were not successful, respiratory protection was worn. The air was monitored continuously or intermittently depending on the probability of airborne material and the degree of surface contamination associated with the operation.

Where the probability of air contamination existed and the concentration of airborne materials was unknown, it was assumed to be above the PAL until determined differently.

Surface contamination was recognized a potential source of airborne contamination and was controlled accordingly. The Contamination Index was derived as an indicator of the level of protection that would be required. Based upon four ranges of the value of this index, measures were implemented for employee protection. The first range denoted an uncontaminated surface. The second level denoted a slight level of contamination, but not to a level where a potential hazard is indicated. The supervisor made available radiation monitoring instruments and advised the employee of the same.

An index at the third level resulted with a continuous air-monitoring program (possibly supplemented with periodic surveys), a routine industrial check for the employee with the requirement to have open wounds tightly bandaged during work, mandatory respiratory protection on certain jobs (including company clothing) and no smoking or eating in the work location without thorough hand washing. Smoking and eating in the work location were prohibited as conditions warranted.

The fourth and highest level also required respiratory protection, company-issued clothing (including coveralls, shoes and head covers).

Penetrating radiation hazards were controlled by limiting the amount of working time in the immediate area, isolation by distance (including remotely operated handling devices), and shielding (e.g., heavy aprons and lead impregnated gloves).

Transfer of Equipment. Property transfer forms included a space to identify the contamination status of the particular item and helped to prevent the spread of contamination from one area to another. In addition, radiation tags on shipped items were used to denote penetrating radiation or alpha contamination. Any shipment had to meet the applicable requirements of the Atomic Energy Commission, Interstate Commerce Commission, U.S. Coast Guard, Civil Aeronautics Board and the U.S. Post Office Department.

Items were released to commercial channels only if they met the appropriate limits for non-contaminated items. Uranium contaminated scrap could be sold to commercial channels if it was in a condition that it could be adequately monitored and it met the appropriate limits. With special authorization from the plant superintendent, limited quantities of scrap contaminated in excess of those levels, but from which enriched uranium had been recovered as completely as possible, could be released for remelting, based upon the alpha activity.

There were strict practices for the receipt of contaminated materials, as well as the shipment of the same from plant to plant. Storage of these materials had to be segregated from those that were not contaminated.

Waste Disposal. Burnable waste was incinerated, beta-gamma contaminated waste was delivered to another installation for burial, and contaminated liquid waste was disposed of in accordance with plant specifications. Contaminated metals meeting contamination levels for

release could be sold. Other unburnable waste was delivered to the contaminated scrap metal yard.

2.4.2.5 Area Surveys

Three types of area surveys were employed at ORGDP: the Work Location, the Equipment, and the Audit survey.

The Work Location survey was performed by the operating group. The group routinely monitored the entire work area in locations where radioactivity was suspected or known to exist. Monitoring included alpha and beta-gamma surface and wipe activity, beta-gamma penetrating radiation levels, and the extent of airborne radioactive contaminants. Monitoring was performed with instrumentation that was the responsibility of the operating group.

Equipment surveys included temporary jobs in which process and related systems were opened and could possibly cause contamination of adjoining clean areas. When ordering maintenance work on this type of equipment, the operating group arranged for the purging and preparation of the systems for entry. The group advised the maintenance group of the type and extent of hazard involved and monitored to determine activity levels. A system of Hazardous Work Permits provided a positive control for all entries into the contaminated process system.

Audit surveys were scheduled on a non-routine basis, performed by the staff groups, and then reported to the line organization. These surveys included a large variety of monitoring activities/spot checks to provide an independent assessment of the radiological and hazardous conditions present in the workplace.

2.4.2.6 Personnel Monitoring

Monitoring for personnel contamination and possible exposure was accomplished through several methods.

Film badges or film rings were requested by supervisors for those employees routinely assigned to work in areas where penetrating radiation was likely to be encountered. Supervisors would also request the termination of this service when it was no longer required. Used film was processed biweekly, with quarterly summaries submitted to the supervisor.

In all areas where process equipment was used, visitor badges were maintained for use by visitors or by employees assigned to that area on an intermittent basis. These badges were processed the same manner as badges for the regular employees.

Local supervision assigned pocket chambers and dosimeters to employees, with a listing of all employees recorded on IBM records. Readings were obtained, and the results were recorded daily. Each week the IBM records were forwarded for inclusion in the plant exposure record, and the results of readings were summarized in the quarterly reports to the appropriate supervisors.

Employees were expected to perform hand counts during the course of their work as the need arose and prior to eating or leaving the plant. The recorded results were forwarded for inclusion in the plant exposure record.

Spot checks were made periodically to determine the extent of on-the-job contamination. A listing of the employees working with radioactive materials was furnished to the Medical Department by the supervisor. The type of work and exposure was evaluated, and employees were scheduled for periodic clinical examination, accordingly.

All employees working with radioactive materials were placed on a routine urinalysis program. Personnel whose job assignments posed higher potential for exposure were subject to an increase in frequency in the submittal of their urinalysis samples.

2.5 ENVIRONMENTAL IMPACT OF RU CONSTITUENTS

Process knowledge and a review of documentation narrowed activities that involved potential environmental contamination by the RU constituents of concern to two activities: ^{99}Tc vented to the atmosphere from the cascade and discharges of RU constituents in sludge from K-1420 to the K-1407-B and –C holding ponds. Quarterly news releases on environmental radioactivity levels at the Oak Ridge Gaseous Diffusion Plant from 1959 through 1964 report data gathered from air monitoring (for atmospheric contamination by long-lived fission products and alpha-emitting materials), water monitoring, and gamma measurements. [6]

2.5.1 Air Monitoring

Atmospheric contamination by long-lived fission products and fall-out occurring in the general environment of East Tennessee were monitored by two systems of monitoring stations during 1959–1964. One system consisted of seven stations that encircled all the plant areas and provided data for evaluating the impact of all DOE Oak Ridge operations on the immediate environment. A second system consisted of eight stations encircling the Oak Ridge area at distances of from 12 to 120 miles. Sampling was accomplished by passing air continuously through filter paper. The data collected were accumulated and tabulated in average μc/cc of air sampled. Figures 2.5-1 and 2.5-2 show the locations of both the perimeter and remote continuous air monitoring stations.

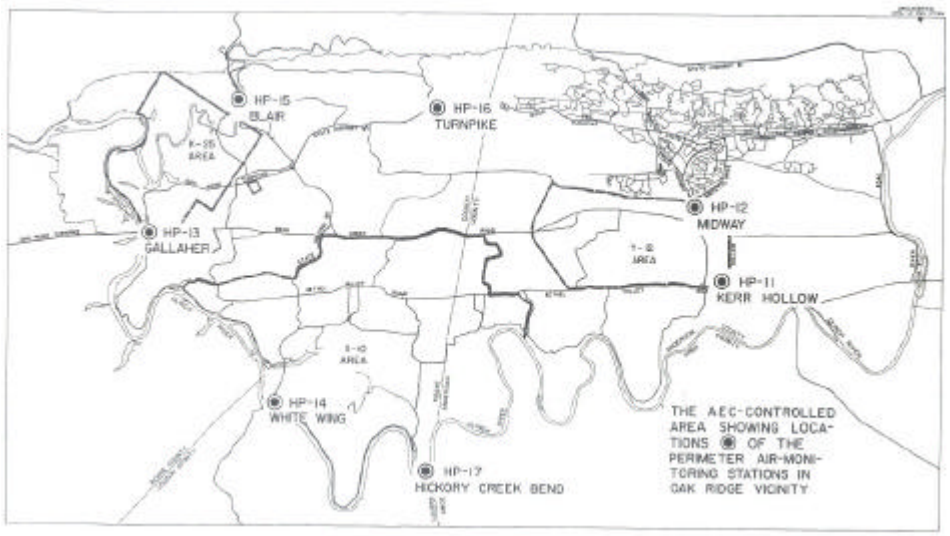

Fig. 2.5-1. Station Sites for Perimeter Air Monitoring System.

[6] News Releases, "Environmental Radioactivity Levels, the Oak Ridge Gaseous Diffusion Plant," Oak Ridge Gaseous Diffusion Plant, January 1959 through June 1964.

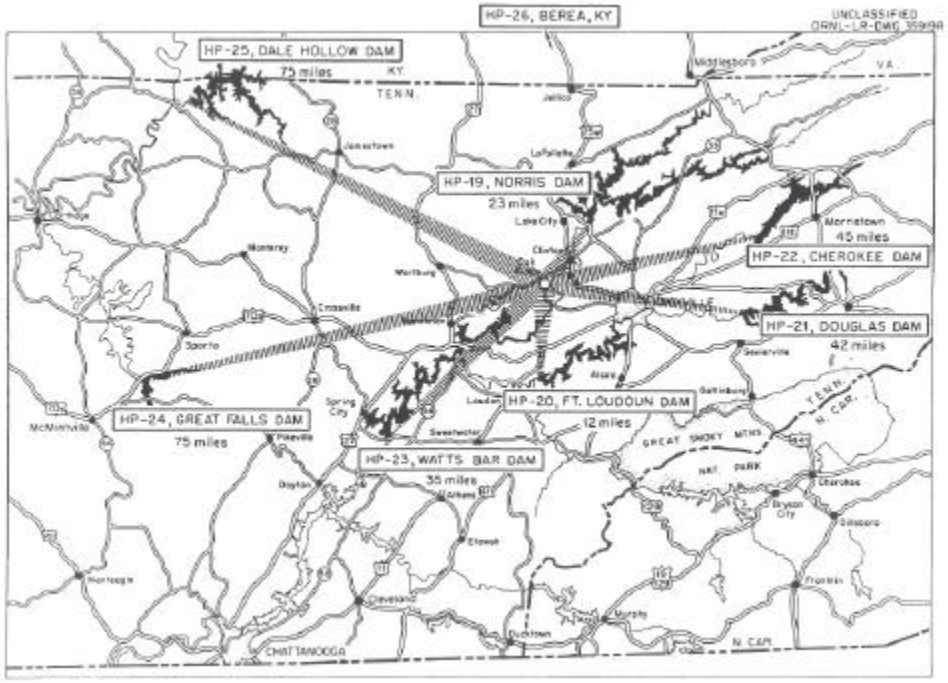

Fig. 2.5-2 Station Sites for Remote Air Monitoring System.

Summaries of the data for the perimeter and remote stations are shown in Tables 2.5-1 and 2.5-2.

Table 2.5-1. Continuous Air Monitoring Data – Perimeter Stations
Long-Lived Gross Beta Activity of Particulates in Air

Year	Period	Number samples (range)	Max*	Min*	Average*	% of MPC**
1959	year	49-52	81.31	0.08	15.76	1.6
1960	Q1	13	2.99	0.24	1.08	0.11
1960	Q2	13	4.22	0.21	1.63	0.16
1960	Q3	14	2.86	0.07	0.85	0.09
1960	Q4	13	1.80	0.04	0.46	0.05
1961	Q1	13-14	1.65	0.0	0.6	0.06
1961	Q2	13-14	8.51	0.18	1.19	0.12
1961	Q3	14	157.0	0.07	20.9	2.1
1961	Q4	13	73.0	16.0	35.0	3.5
1962	Q1/Q2	26-74	90.0	22.0	41.0	4.1
1962	Q3/Q4	26-74	81.0	11.0	30.0	3.0
1963	Q1/Q2	26-181	131.0	27.0	60.0	6.0
1963	Q3/Q4	26-180	69.0	3.0	20.0	2.0
1964	Q1/Q2	26-180	35.0	4.0	13.0	1.3

* *Units of 10^{-13} mc/cc*

** *Maximum Permissible Concentration (MPC) is taken to be 10^{-10} mc/cc as recommended in NBS Handbook 69*

Table 2.5-2. Continuous Air Monitoring Data – Remote Stations
Long-Lived Gross Beta Activity of Particulates in Air

Year	Period	Number Samples (Range)	Max*	Min*	Average*	% of MPC**
1959	year	26-52	100.52	0.14	13.97	1.4
1960	Q1	13	2.73	0.12	1.14	0.11
1960	Q2	10-13	3.11	0.08	1.65	0.17
1960	Q3	11-13	2.39	0.16	0.8	0.08
1960	Q4	12-13	2.66	0.12	0.49	0.05
1961	Q1	13-14	1.18	0.0	0.55	0.06
1961	Q2	13-14	2.22	0.2	0.95	0.1
1961	Q3	14	220.0	0.07	23.6	2.4
1961	Q4	13	88.0	15.0	41.0	4.1
1962***	Q1/Q2	26	97.0	20.0	49.0	4.9
1962	Q3/Q4	26	159.0	11.0	36.0	3.6
1963	Q1/Q2	25-26	114.0	35.0	63.0	6.3
1963	Q3/Q4	25-26	91.0	4.0	24.0	2.4
1964	Q1/Q2	25-26	48.0	4.0	17.0	1.7

* *Units of 10^{-13} mc/cc*
** *Maximum Permissible Concentration (MPC) is taken to be 10^{-10} mc/cc as recommended in NBS Handbook 69*
*** *The Berea, Kentucky remote station provided no samples after 1961*

The highest percent Maximum Permissible Concentration (MPC) values for the perimeter and remote monitoring stations for the period were in the first half of 1963 and were reported as 6% and 6.3%, respectively. The news release for that period states that: "Although these values are approximately two times greater than the average for the last half of 1962, they are no greater than the average of those measured in other areas of the United States and reported by the U.S. Public Health Radiation Surveillance Network for the period January through May 1963."

Beginning in 1961, atmospheric contamination by uranium was determined by taking periodic air samples at eight locations on a five-mile radius from the ORGDP. An average of 16 random, 10-minute samples were taken each quarter. Beginning in the fourth quarter, 1961, the analysis performed changed from uranium concentration to gross alpha, and the sampling methodology changed from random to continuous. The results are shown in Table 2.5-3.

Table 2.5-3. ORGDP Air Monitoring Data

Year	Period	Number of Samples	Direction from Plant				Average*	% MPC_a
			North*	East*	South*	West*		
1961	Q1	16	0.0	0.33	0.25	0.75	1.03	5.0
1961	Q2	16	0.5	0.75	1.8	1.4	1.3	6.5
1961	Q3	10	0.75	0.5	0.35	0.25	0.45	2.3
1961**	Q4	592	3.0	1.6	2.6	1.8	2.4	12.0
1962	Q1/Q2	2279	1.7	1.6	1.7	1.6	1.6	8.0
1962	Q3/Q4	2431	2.8	3.6	3.0	4.6	3.3	17.0
1963	Q1/Q2	2346	1.7	1.7	2.3	3.5	2.2	11.0
1963	Q3/Q4	1418	2.5	5.0	2.5	***	4.0	20.0
1964	Q1/Q2	1595	3.0	4.5	4.0	***	3.5	18.0

* *Units of 10^{-13} mc/cc*
** *Beginning in Q4 1961, the analysis changed from uranium concentration to gross alpha and the sampling methodology changed from random to continuous*
*** *Sampling locations changed from N, E, S, & W to N, NE and SW.*

The highest value for the approximate 5-year period was 20% of the MPC for air (MPC_a) for populations in the neighborhood of a controlled area.

2.5.2 Water Monitoring

Liquid wastes originating at ORGDP and the Y-12 Plant were discharged to Poplar Creek, which flows into the Clinch River. Releases were controlled to enable resulting average concentrations in the Clinch River to comply with the maximum permissible levels for populations adjacent to DOE facilities as recommended by the National Committee on Radiation Protection (NCRP). Water was sampled at a number of locations in the Clinch River, beginning at a point of entry of wastes into the river (mile 20.8) and ending at Center's Ferry near Kingston, Tennessee (mile 4.5). The average concentration of radioactivity at these two points was then calculated. The average concentration of TRU alpha emitters at mile 20.8 was also calculated. Stream-gauging operations were carried on continuously by the U.S. Geological Survey to obtain dilution factors for calculating the probable concentrations of wastes in the river. The average activity in Poplar Creek was also reported in 1959 and 1960. These results for the five-year period are shown in Table 2.5-4 as percentages of the MPC for water (MPC_W) for populations in the neighborhood of a controlled area.

Table 2.5-4. ORGDP Water Monitoring Data

Year	Period	% MPC_W (Clinch River)*		% MPC TRU alpha emitters (Clinch River)	% MPC activity (Poplar Creek)
		Mile 20.8	Mile 4.5		
1959	year	25.4	22.3	0.03	0.03
1960	Q1	26.9	16.4	0.002	0.02
1960	Q2	23.2	7.9	0.001	0.03
1960	Q3	12.6	4.9	0.001	0.04
1960	Q4	22.0	17.0	0.0004	
1961	Q1	33.0	13.0	0.0007	
1961	Q2	21.0	7.0	0.0005	
1961	Q3	6.3	3.1	0.003	
1961	Q4	8.8	5.5	0.0001	
1962	Q1/Q2	8.2	6.2	0.0002	
1962	Q3/Q4	6.4	3.9	0.0003	
1963	Q1/Q2	5.6	3.4	0.0002	
1963	Q3/Q4	3.3	4.0	0.0002	
1964	Q1/Q2	3.5	2.0	<0.001	

**The fraction of the total beta activity comprised by each isotope was determined from analysis of long-lived radionuclides contained in the effluent and a weighted average maximum permissible concentration for water (MPC_W) for the mixture of radionuclides is calculated on the basis of the isotopic distribution using the MPC values of each isotope as recommended by the NCRP. The average concentration of gross beta activity in the Clinch River was compared to the calculated MPC_W values. The concentration of uranium was compared with the specific MPC_W value for uranium.*

There were no instances of water release at ORGDP boundaries above the long-term MPC concentrations.

2.5.3 Gamma Measurements

External gamma radiation levels were measured monthly at a number of locations in the Oak Ridge area. These locations included Solway Gate, Y-12 Plant East Portal, Newcombe Road in Oak Ridge, Gallaher Gate, and White Wing Gate. Measurements were taken with a Gieger-Muller tube at a distance of three feet above ground, with the results tabulated in mr/hr. These results are shown in Table 2.5-5.

Table 2.5-5. External Gamma Radiation Levels (mr/hr)

Year	Period	Average
1959	year	0.024
1960	Q1	0.017
1960	Q2	0.020
1960	Q3	0.020
1960	Q4	0.020
1961	Q1	0.015
1961	Q2	0.020
1961	Q3	0.019
1961	Q4	0.020
1962	Q1/Q2	0.027
1962	Q3/Q4	0.031
1963	Q1/Q2	0.028
1963	Q3/Q4	0.023
1964	Q1/Q2	0.014

The news releases state that "These average levels were the same as average background levels obtained throughout the United States by the U.S. Public Health Service Radiation Surveillance Network, employing similar methods and detection instruments."

A historical compilation of radionuclide release data was published in the 1986 *Oak Ridge Gaseous Diffusion Plant Historical Uranium and Radionuclide Release Report,* K/HS-95. This report documented releases from 1946 through 1984 and included data on the radionuclides associated with RU feed material, including transuranics and fission products. These data are presented in Section 4.7 of this report.

A joint task force was assembled by DOE in 1985 to study past and current practices related to processing of RU materials. From the data reviewed, the task force did not disclose any instance in which the environment or the safety or health of plant workers or the public were jeopardized or compromised. The primary recommendation for gaseous diffusion plant operations from this study was to develop formal specifications on maximum permissible levels of contaminants in enrichment feed materials. This study is documented in the DOE's 1985 *Report of the Joint Task Force on Uranium Recycle Materials Processing.*[7]

An Oak Ridge Dose Reconstruction Project was initiated in 1994 as follow-up to the Oak Ridge Dose Reconstruction Feasibility Study, which recommended a closer examination of the past uranium emissions and potential resulting exposures. The initial feasibility study performed

[7] D. Egli, et al., *The Report on the Joint Task Force on Uranium Recycle Materials Processing,* DOE/OR-859, U.S. DOE Oak Ridge Operations, September 1985.

screening calculations to identify those operations and materials that warranted detailed investigation in terms of potential off-site exposures to the individuals that have lived in the areas surrounding the Oak Ridge Reservation (ORR). At the close of the feasibility study, the Tennessee Department of Health and the Oak Ridge Health Agreement Steering Panel (ORHASP) recommended that a detailed project—including dose reconstruction—be performed. The results of a portion of this project were documented in the July 1999 Task 6 report entitled *Uranium Releases from the Oak Ridge Reservation—a Review of the Quality of Historical Effluent Monitoring Data and a Screening Evaluation of Potential Off-Site Exposures.*[8]

The Task 6 component of the project involved further evaluation of Oak Ridge uranium operations and effluent monitoring records to determine if uranium releases from the ORR likely resulted in off-site doses that warranted further study. The team performed a historical review of air and water release data, including health physics and industrial hygiene reports, stack monitoring data, accident and investigation reports, logbooks, and procedures for the period 1944 through 1988.

The Task 6 team concluded that estimates of uranium releases were underestimated by the Atomic Energy Commission (AEC), DOE, and ORR site contractors. One major reason for the discrepancies at ORGDP involves releases from the S-50 Liquid Thermal Diffusion Facility. As an experimental predecessor to gaseous diffusion technology, this facility is considered one of the major undocumented (or partially documented) sources of historic uranium releases from the ORR. These losses were not included in prior DOE/AEC/ORGDP release estimates because, during its short 12-month operation in 1944-1945, S-50 was not considered part of ORGDP operations. The K-1131 feed plant and the K-1420 decontamination facility together represent the source of approximately 50% of the total material unaccounted for at ORGDP. Uncertainties and insufficient data for cascade releases, stack sampling, and water pathways such as storm sewer drains and settling ponds all were found to have the potential to add additional quantities of uranium to the Task 6 release estimates.

The evaluation of uranium airborne releases from the K-25 Complex (i.e., ORGDP and S-50) was based on analysis of uranium accountability records and incident reports, calculation of purge cascade releases from monitoring data, and results of periodic monitoring in three buildings at ORGDP. Estimates of airborne uranium releases over time were generated from the data gathered. The total mass (kg) of uranium released to the atmosphere from the K-25 Complex for the period 1944 through 1995 was estimated to be 16,000 kgU. Figure 2.5-3 shows the release estimates plotted over time.

The screening evaluation of potential off-site exposure to waterborne uranium was based on environmental measurements of uranium in local surface waters. Reported annual average uranium concentrations in the Clinch River were used for the Task 6 screening evaluation. These values were based on water samples collected at the confluence of Poplar Creek and the Clinch River for all the years of operation, up to 1995. Effluent monitoring data were also evaluated for quality and consistency with previous DOE historical uranium release reports. The average annual concentration of uranium in the Clinch River for the period 1944–1995 was estimated to be 0.015 mgL^{-1}.

[8] *Reports of the Oak Ridge Dose Reconstruction, Vol.5, The Report of Project Task 6: "Uranium Releases from the Oak Ridge Reservation—a Review of the Quality of Historical Effluent Monitoring Data and a Screening Evaluation of Potential Off-Site Exposures,"* July 1999.

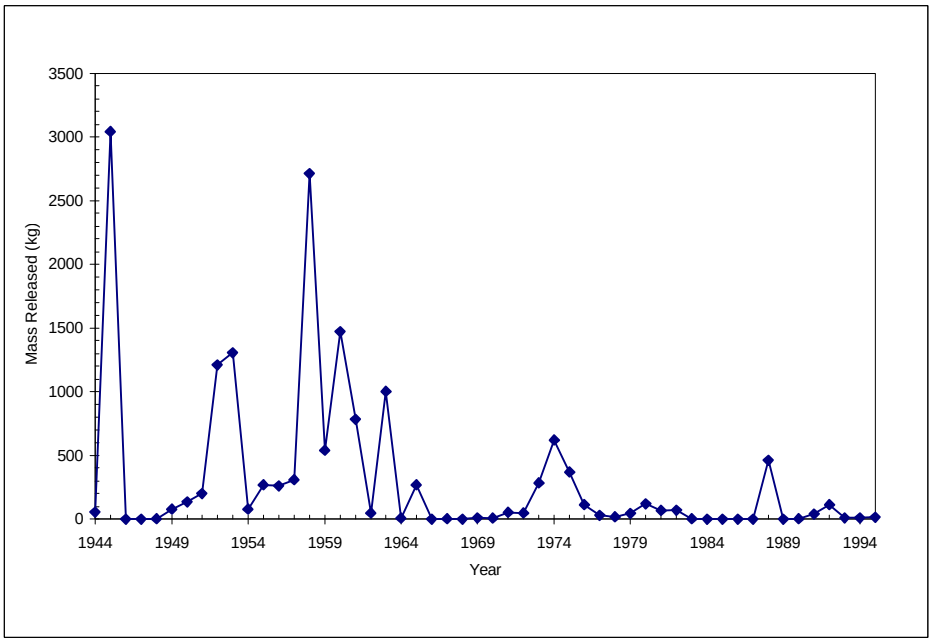

Fig. 2-5-3. Estimates of Annual Airborne Uranium Releases from the K-25/S-50 Complex.

Based on the decision guidelines from the ORHASP, the Task 6 team concluded that the uranium releases from the K-25 Complex are candidates for further study, but that they are not high priority candidates. Instead, further characterization of the extent of uranium contamination in soils should be evaluated for potential exposures to nearby residents.

The Task 7 component of the Oak Ridge Dose Reconstruction effort involved the screening of additional potential materials of concern, including Np and ^{99}Tc. This portion of the effort was documented in the July 1999 Task 7 report entitled *Screening-Level Evaluation of Additional Potential Materials of Concern.*[9]

2.5.4 Neptunium

The Task 7 team identified no historical stack monitoring or ambient air monitoring data for Np. Therefore, Np sources for ORGDP were estimated based on RU material sent to each plant. In the 1988 DOE Report *Historical Radionuclide Releases from Current DOE Oak Ridge Operations Office*, DOE reported releases of Np in liquid wastes from 1979 through 1983.[10] However, DOE did not provide estimates for air releases of Np. The Task 7 team therefore estimated the total annual Np activity released from ORGDP by using a three-step process: calculate the mass of RU received annually at ORGDP; calculate the Np activity based on the mass of RU received annually and the specific activity of Np; and calculate the Np activity released to the air per year based on the uranium release fraction and the assumption that the Np fraction was equivalent to the uranium release fraction. Np concentrations were calculated based on the uranium upper alpha activity of 200,000dpm g^{-1} (Egli et al., 1985). It was recognized that

[9] *Reports of the Oak Ridge Dose Reconstruction, Vol.5, The Report of Project Task 7: "Screening-Level Evaluation of Additional Potential Materials of Concern,"* July 1999.
[10] U.S. Department of Energy. *Historical Radionuclide Releases from Current DOE Oak Ridge Operations Office*, ORO-890, U.S. DOE Oak Ridge Operations, 1988.

the calculated estimate would be conservatively high because the alpha activity in uranium is a result of uranium, Pu, and Th, as well as Np. Table 2.5-6 provides the estimated airborne releases of Np per year from ORGDP for the period 1953 to 1995.

Table 2.5-6. K-25 Np-237 Release Estimates

Year	Air Release (mCi)	Water Release (mCi)
1953	110.0	2.2
1954	48.0	2.2
1955	50.0	2.2
1956	24.0	2.2
1957	24.0	2.2
1958	140.0	2.2
1959	39.0	2.2
1960	72.0	2.2
1961	54.0	2.2
1962	13.0	2.2
1963	49.0	2.2
1964	2.3	2.2
1965	13.0	2.2
1966	1.7	2.2
1967	1.6	2.2
1968	2.2	2.2
1969	2.9	2.2
1970	2.3	2.2
1971	3.4	2.2
1972	3.9	2.2
1973	6.5	4.5
1974	14.0	1.1
1975	0.81	1.1
1976	2.4	0.56
1977	1.5	1.7
1978	1.5	1.7
1979	1.5	1.5
1980	1.5	1.4
1981	1.5	2.1
1982	1.5	1.9
1983	1.5	0.4
1984	1.5	2.2
1985	1.5	2.2
1986	1.5	2.2
1987	1.5	2.2
1988	1.5	2.2
1989	1.5	2.2
1990	1.5	2.2
1991	1.5	2.2
1992	1.5	2.2
1993	1.5	2.2
1994	1.5	2.2
1995	1.5	2.2
TOTAL (mCi)	710.0	88.0

Estimates of waterborne Np releases at ORGDP from 1979 to 1983 were also provided in the DOE *Historical Radionuclide Releases from Current DOE Oak Ridge Operations Office*. The annual environmental monitoring reports provide waterborne release estimates for transuranics from the ORR for the period 1973 to 1986. Estimates for Np releases for these years were calculated as a fraction of the total transuranics released. For the years that no data were available, annual Np releases to water were assumed to be equal to the 95% of the upper confidence limit (UCL) of measured and estimated Np from 1973 to 1983 (0.0022 Ci)—a representative period of active equipment decontamination and barrier replacement. Table 2.5-6 presents ORGDP Np annual waterborne release estimates in mCi for the period 1953 to 1995.

2.5.5 Technetium

^{99}Tc is present in the environment as a result of global fallout from nuclear weapons testing and of nuclear fuel reprocessing worldwide. This man-made background source would become a part of ongoing measurements performed on or around the ORR. The estimated average concentration of ^{99}Tc in soil worldwide due to global fallout from nuclear weapons tests is 2.2 pCi kg^{-1}.[11]

Historical measurements of ^{99}Tc in the environment near the ORR are extremely limited. The Task 7 team did not locate any information regarding airborne releases of ^{99}Tc prior to 1974. However**,** the 1978 *Draft Mass Balance, ORGDP* provides an estimate of the amount of ^{99}Tc received at ORGDP from 1953-1977,[12] and the team used these ^{99}Tc quantities to estimate the total ^{99}Tc releases. To calculate releases of ^{99}Tc to the air, the material balance report assumed that there were two release points to the atmosphere: the K-1131 feed plant stack and the purge cascade vent. K-1131 was shut down in the early 1960s and would not have contributed to releases beyond that time period. The material balance report assumed that the ORGDP feed plant functioned similarly to the PGDP facility, where an estimated 5% of the ^{99}Tc in the UO_3 was vented to the atmosphere during fluorination. A 5% release fraction applied to the 8.6 kg of ^{99}Tc received each year yields a calculated annual release of 0.43 kg (7.3Ci) of ^{99}Tc from the K-1131 stack from 1953 to 1962. For the second source of airborne ^{99}Tc releases from ORGDP (the purge cascade), the material balance report estimates airborne releases from 1953 to 1973 by averaging the purge cascade monitoring data for 1974 to 1976. The average release of 2.5 Ci per year from the purge cascade over this three-year period was applied to earlier time periods (1953 to 1973). In 1977, a scrubber was installed on the purge cascade vent, which resulted in a considerable decline in ^{99}Tc airborne releases. From 1978 through 1995, the screening analysis used release estimates reported in the annual environmental monitoring reports.

No measurements of ^{99}Tc concentrations in liquid effluent from ORGDP prior to the late 1980s were identified by the project team. Beginning in 1987, concentrations of ^{99}Tc were measured monthly in Poplar Creek. Concentrations from 1987 to 1995 ranged from less than the limit of detection to 1,860 pCi/L^{-1}. During this same time period, concentrations downstream in the Clinch River ranged from less than the limit of detection to 1,640 pCi/L^{-1}.

Based on the qualitative and quantitative screening performed by the Task 7 team, Np material used at ORGDP was judged not to warrant further study. ^{99}Tc was identified as one of the potential candidates for further study, but was not identified as a high priority.

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[11] F. O. Hoffman, *Environmental Behavior of Technetium in Soil and Vegetation: Implications for Radiological Impact Assessment*, ORNL-5856, Oak Ridge National Laboratory,1982.

[12] *Draft Mass Balance, ORGDP*, Oak Ridge Gaseous Diffusion Plant, 1978 (from Box 8-3-5, K-25 Site Records Center).